RESPONSE TO TAC COMMENTS

ON

"ASSESSMENT OF NUTRIENT LOADING AND EUTROPHICATION IN BARNEGAT BAY-LITTLE EGG HARBOR, NEW JERSEY IN SUPPORT OF NUTRIENT MANAGEMENT PLANNING"

Prepared for:

New England Interstate Water Pollution Control Commission

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General Response to TAC Comments

- This project focuses on assessment of nutrient loading and eutrophication in support of nutrient management planning. Many comments consider topics beyond the scope of this project and mandates of the QAPP. Examples include (but are not limited to) the nuclear power plant, recreational/commercial boat traffic and personal watercraft, shoreline hardening, etc. The project, report, and response to comments, and revisions to the report must be bound to the scope described in detail in the QAPP.

- This project focuses on the time period 1989-2010, with 2011 data used as verification of the results of this project's analysis. Data collected prior to or after the scope of this project cannot be considered for analysis, inclusion, or discussion in the report.

- There were several comments requesting specification of the thresholds used for various indicators. These thresholds have previously been specified multiple times in presentations and progress reports. They are repeated here in Tables 3-2, 3-8, 3-10, 3-11, and 3-12. The equation of the trendline between the thresholds and the scores are used to create the rescaling equations. To attempt to streamline the report, the rescaling equations were summarized into a table rather than including individual graphs showing defined thresholds and scores for each indicator. To avoid confusion and increase transparency, the revision of the report re-inserts all thresholds for each indicator, listed in tables for clarity and to save space.

PAGE 1 of the TAC Comments (General Comments)

Second paragraph: "An important expectation of this report was to determine the degree to which various stressors are responsible for the observed condition of Barnegat Bay. In addition, if possible, the threshold levels for each relevant stressor that would result in an impaired vs. unimpaired condition. To be useful in crafting a management strategy, it is essential to know both the relative importance of the suite of stressors that are responsible for the observed biotic condition, and the threshold for each stressor that aligns with an acceptable biotic condition. The elements of an effective management plan would depend on 1) which factors have the greatest influence on biotic condition, 2) which ones are most outside of the range needed for an acceptable biotic condition and 3) which factors can be remediated most cost effectively."

- This report meets the expectation outlined in the following ways. 1) Examining condition of Barnegat Bay with respect to many various stressors. 2) Establishing threshold levels for each stressor that, in conjunction with the other multiple interacting factors, results in response by the ecosystem with an assessment of the ecosystem condition. 3) Identifying the relative importance of each stressor as contributing to the overall observed biotic condition.
- Ecosystems are complex, in that multiple stressors and factors interact resulting in observed biotic and ecosystem response. Simply put: there are many moving parts. A unique and static threshold for each stressor that results in an impaired vs. an unimpaired condition is simplistic and inaccurate and managing for such conditions will very likely not result in anticipated or desired outcomes. Rather, there is a continuum of multiple stressors, and a continuum of conditions from unimpaired to impaired. The report and its products embrace this complexity to provide information as accurate as possible given the inputs of available data, and we hope that this information will be useful in crafting a

management strategy.

- This report can help to inform management plans by identifying which factors have the greatest influence on biotic condition, and identifying which stressors are outside of a range needed for acceptable biotic condition. However, it must be understood that these ranges and factors have complicated interactions, and none operate individually or statically. It is outside the scope of this project and this report to identify the factors that can be remediated most cost effectively. Neither cost-effectiveness nor remediation is mentioned in the QAPP. Hence, this project is **in support of** nutrient management planning, but does not overstep its bounds by presuming to develop an effective management plan.

PAGE 1 of the TAC Comments (General Comments)

Third paragraph: "Overall, our evaluation of this report is very mixed, but we do note several notable accomplishments with this study. First, the authors have reviewed and synthesized a tremendous amount of information from the watershed. More importantly, the land use/ USGS loading study provide a considerable amount of new information (land use, loading patterns) which has diverse uses to our efforts to reduce nutrient loading to the bay. Lastly, development and review of the eutrophication index suggests some previously unrecognized patterns and trends in the ecology and condition of the bay which merit close scrutiny in our efforts to better understand and protect the bay."

- Thank you. Yes, this report represents a large amount of work and analysis on the part of all authors. We hope that the products and results are of interest and use to the broader Barnegat Bay-Little Egg Harbor community.

PAGE 1 of the TAC Comments (General Comments)

Fourth paragraph: "Nonetheless, we have considerable reservations about this study in its present format. The overall report is poorly and inconsistently organized; methods are inconsistently and, in some cases, inadequately explained. In particular, the section on the validation of the eutrophication model does not lay out the appropriate methods or results (the fit of the 2011 data to the eutrophication model). The manuscript is oftentimes redundant (e.g., see "Statement of the problem and Scale of Ecosystem change). I find statements throughout the report unsupported by evidence or citations."

- Revisions to this report take a careful look at the organization and explanations provided in this report. Clarity is sought. Redundancy is avoided where possible. Exceptions may be found in repetition of critical details that would otherwise require effort for the reader to locate amid the broad scope of this report. All comments are responded to, including comments regarding validation of the eutrophication assessment.

PAGE 1 of the TAC Comments (General Comments)

Fifth paragraph: "I am troubled by the big picture portrayal (i.e., insidious system-wide decline due to nutrients) when different bay segments have different patterns and trends (and may even be improving?), according to the available data. The authors may be right but, if so, then our understanding of the bay's ecology is lacking and/or missing some sorely needed pieces."

- We agree that the collective understanding of the ecology of BB-LEH has some large and important missing pieces. Water quality monitoring data, particularly dissolved oxygen, are extensive but have not been conducted at ecologically appropriate time scales (i.e. continuous monitoring, or at minimum multiple grab samples per day at many locations, to sufficiently characterize BB-LEH with statistical confidence. Secchi depth does not adequately characterize light availability in coastal lagoons where light often penetrates to the bottom but is not fully 'clear', in that suspended particulates, sediments, or plankton and macroalgae may still attenuate light to some degree. Sediment chemistry data, such as sulfide concentrations, nutrient flux, denitrification rates, etc. have not been collected for at least a decade. Seagrass data do not extend backward in time far enough to identify a 'pristine' condition. Widgeon grass data in the north segment have only been collected since 2011 and many additional years of data are necessary to fully understand its dynamics within this ecosystem. Benthic invertebrate data have not been collected at temporally or spatial extents to adequately characterize the condition of benthic invertebrate communities or utilize them as an effective indicator of ecosystem condition. However, by documenting the limitations of the existing data, we hope that such data gaps can be addressed in the future through additional monitoring and research efforts.
- Despite the limitations of the existing database, which we readily acknowledge, we are confident that the statements made in this report are as accurate as possible. Big picture statements are made with the acknowledgement of the database upon which they rely. We have carefully considered the statements that are made at both the segment and estuary-wide scales.

PAGE 1 of the TAC Comments (General Comments)

Sixth paragraph: "The water quality data collected as part of this project should be provided including, for each sample, value for each parameter, date and time collected, and GPS location (latitude and longitude), and depth, along with a map of the sample locations."

- The water quality data used for this project was collected by NJDEP Bureau of Marine Water Monitoring, courtesy of Robert Schuster. This dataset contains a large amount of data that was considered to large to be included in the text of this report, hence its annual summary for each segment of the estuary.

PAGE 1 of the TAC Comments (Comments on Report Organization)

Seventh paragraph: "The organization of the report is awkward and redundant while missing critical details, which made review challenging."

Where the TAC has pointed out redundancies and sections that can be reordered or streamlined, we have done so as specified below in the appropriate sections. We add or clarify details where requested as indicated below.

PAGE 2 of the TAC Comments (Comments on Report Organization)

First paragraph: "Some concerns about this report arise from the task of integrating so much information; this requires that the organization of the sections and the information within each section be as consistent and concise as possible. Many sections are redundant and repeat material from previous sections. Wherever possible, redundancy should be eliminated."

- Where suggestions for organization have been indicated, we have responded and reorganized the report to improve its flow and readability as best as possible given the complex, highly technical subject matter and level of detail required to fully communicate the methods, results, implications, and importance of the project conducted.
- We included information required for each section individually. Specifics are listed below.
- We omit redundant information where possible. Specifics are listed below.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON SEPARATE SURVEY)

"Data from a separate survey were used as part of the project but no details were given on how these were integrated, particularly since the seagrass species are different between the sections of the Bay."

- We presume that the separate survey mentioned was the 2011 survey that included the northern segment transects. Note that this report can only document the results, findings, and conclusions based on the scope of work specified in detail in the QAPP from this project. Only secondary data specified in the QAPP can be considered for evaluation and reporting for this project. The results from the northern segment transects in 2011 are documents, reported, and summarized in a separate report as specified in the QAPP for that project and submitted to the appropriate funding agency.
- Note however that the QAPP does mention including data from 2011. The 2011 data are shown in Chapter 4, summarized in the tables and figures, and are used as validation data for the Eutrophication Index. With respect to seagrass, the survey encompassed both *Zostera marina* and *Ruppia maritima.* We do note that currently additional data for *R. maritima* are needed for validation and comparison purposes. However, other data such as nutrient loading, water quality, and light availability can be readily compared across segments of BB-LEH.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON RAW DATA)

"USGS and Rutgers raw data should be supplied to EPA and NJDEP. This should include GPS coordinates and QC information."

- USGS and Rutgers raw data are available and will be supplied to EPA and NJDEP.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON REMOTE SENSING DATA)

"The QAPP (pg. 58 stated that remote sensing data were going to be used as part of this project to assess bay-wide seagrass distribution but there does not appear to be discussion of whether this was done or what the results were."

These data have been compiled and analyzed. A final report is appended to the NEIWPCC report (Appendix 2-1). General findings include the following. An estuary-wide survey was conducted in the summer of 2009 to measure the current extant of seagrass habitat across the BB-LEH system (Lathrop and Haag, 2011). Aerial imagery collected during the months of July and August 2009 was interpreted and mapped using an object oriented image analysis technique, similar to techniques used in the 2003 mapping survey. A boat-based *in situ* dataset was collected concurrently with the aerial photography to assist the image interpretation and for an independent accuracy assessment. Lathrop et al. compared the remotely sensed mapping of seagrass cover change (in 2003 vs. 2009) vs. the *in situ* plot-based sampling conducted by Kennish et al. from 2004 through 2010. Comparison of the remotely sensed vs. the *in situ* plot change analysis suggests that the two methodologies had broadly similarly results with the percent area showing declines in percent cover was greater than those that exhibited increases. In conclusion, the two studies provide corroborating evidence that seagrass has declined in percent cover in the BB-LEH system during the decade of the 2000's.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON METHODOLOGY)

"General Question on how the raw scores are determined: Are the raw scores determined by observed data input into an equation and then turned into a dimensionless unit? Or are the raw scores not all observed data but picked on best professional judgment, literature, and observed values?"

- Raw scores are the output of equations that use observations as inputs and thresholds (determined by literature, observed values, and best professional judgment) for parameterization.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON METHODOLOGY)

"Unfortunately, the methods are inconsistently organized among sections and poorly described within some sections. This is particularly true in the index development and the model validation section. The report should more simply and concisely present the methods, including the data collection of data, statistical tests used to analyze the data, and identify one or more appropriate citations regarding their use."

- The methods and many sections of this report have been reorganized to improve the flow and readability of the document. This report has multiple components, and methodology is described in sections we believe will be most helpful to the reader. Care has been paid to the revision of the index development and model validation sections. The methods are presented more simply and concisely. This is the case for data collection and statistical tests. Citations have been added throughout the document as appropriate to support and justify statements.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON METHODOLOGY)

"The purpose for including some data and/or methods in the project is not sufficiently clear, even in cases where I think we are in agreement regarding the results and their interpretation. For example, we have many measures of eelgrass condition included in the eutrophication index. What is the benefit of incorporating and analyzing so many different metrics for eelgrass? The utility of the weighting of index scores is unclear; what was the benefit of using weighted and/or final scores? It is not clear what was done in component 4, that is, it is not clear how the model was validated using 2011 data. Component 4 simply presents the results of the data collected during 2011. It should use the model to make predictions of the biological information from the other noted conditions and assess the match between observations and predictions."

- Data and indicators considered for inclusion in the project and the Index of Eutrophication are specified in the QAPP.
- We have clarified the purpose for including data and methods for this project.
- Several indicators associated with seagrass are included in the Index of Eutrophication. We note that biomass, percent cover, and density provide different pieces of information regarding condition of seagrass. We have noted that these characteristics have changed at different rates throughout the study period (Fertig et al. 2012). Further, as *Zostera marina* biomass and blade length have significantly declined over time, shoot density has increased, indicating a physiological response mechanism that may be attempting to compensate for reduced growth opportunities associated with decreased light availability due to increased frequency and intensity of macroalgal blooms (Kennish et al. 2011, Fertig et al. 2012).
- We clarify that index scores are weighted so as to be able to handle temporal or spatial gaps in the data record. Weighted scores provide a measure of the consistency of the observations with respect to thresholds for the appropriate indicator. Consistency is important to include in an Index of Eutrophication because it highlights times and places when and where conditions of each indicator are changing (either positively or negatively) so that these indicators can be targeted for attention (e.g. for monitoring, management, or research). This can help prioritize decisions regarding limited resources available for various actions. For example, if an indicator is in flux, it may be worthy of more intense monitoring, research, or remediation action. If that same indicator consistently exhibited an extreme conditions (e.g. 'Excellent' or 'Highly Degraded') discussions regarding prioritization of resources may be efficiently directed towards another indicator.
- Validation in Chapter 4 was conducted by
    - Monitoring indicators for an additional year and comparing observations to previous years to indicate ecosystem trajectory, discussed in Chapter 5.
    - Applying the Index of Eutrophication to an independent dataset kept separate from the dataset used to build the model.
- Note that the Index of Eutrophication is an assessment tool and not a predictive model per se. As specified in the QAPP (p. 60), the Index of Eutrophication can be used to assess and define ecological impairment. Also as specified in the QAPP (p.1), the Index of Eutrophication is a standard against which future assessments of estuarine impairment can be compared. However, the QAPP does not mention predictive capacity as a desired result of the Index. Predictive capacity is not included as one of the objectives of the Index of Eutrophication. It is therefore not within the scope of this project to make predictions of the biological information from the other noted conditions and assess the match between observations and predictions.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON METHODOLOGY)

"Lastly, the manuscript veers off to address other issues (e.g., NCA sampling design) when discussing methods. The "adequacy" of data depends on their use; criticisms directed at other uses of any data are irrelevant and should not be included in the manuscript."

- All datasets in the report are discussed with respect to their use for this project. The report does not consider adequacy or use for any other project. Many datasets were identified for potential use in this project. All datasets being considered for use in this project must be examined for relevancy and appropriateness for inclusion in this project. Sampling design is one example of many central considerations. For completeness and reporting accuracy, we include such discussions for all datasets that were identified and considered for inclusion in this project regardless of the final conclusion about inclusion/exclusion so as to provide reasoning and evidence for this decision for this project. Therefore, the discussions mentioned above are relevant and remain in the report.

PAGE 2 OF THE TAC COMMENTS (COMMENTS ON METHODOLOGY)

"Thresholds are not clearly defined. As a result the development of raw and weighted scores as well as the overall Index of Eutrophication can't be properly evaluated: The selection of thresholds to be used in the assessment of eutrophication in Barnegat Bay was a topic of discussion at the March 28, 2012 meeting. Similar comments were raised in the comment letter on the April 15, 2012 quarterly progress report. Rutgers provided a response to explain what information would be considered in establishing the thresholds, however, it remains unclear what values were actually used and why."

- We have clearly defined the thresholds and presented these throughout the course of the project, as noted in the TAC comments, on March 28, 2012 and April 15, 2012. Additionally, these were presented in written format, repeatedly, in various quarterly progress reports.
- Thresholds are defined with the purpose of creating a rescaling equation. The rescaling equation is used to calculate Raw Scores. The rescaling equation is simply the trendline that is generated from plots of the thresholds with the defined score on the y axes and the defined threshold for an indicator on each x axis. The rescaling equations were reported in Table 3-2 of the report.
- For the convenience of the TAC, we remind the TAC of the threshold values for each indicator in a series of tables shown below. These are inserted into the revised report as Tables 3-3, 3-8, 3-10, 3-11, and 3-12. The tables, one for each component of the index, indicate the defined score for each threshold for each indicator. The associated rescaling equations remain in Table 3-2.
- Note that since the Ecosystem Pressures only receive Raw Scores, the scores for these indicators range from 0 to 100. This is because there are only two indicators and thus PCA is not meaningful and weightings are thus not calculated. Raw Scores for these indicators are averaged together to create the Pressure Index. Maximum and minimum nutrient loading values for rescaling are listed in Table 3-2. Note that this is also the case for the HAB thresholds, since there is only one indicator used for this component.
- The reasoning, scientific justification, and specific process for the selection and definition of each value of the thresholds has been stated in previous progress reports as well in the

final project report.

Table 3- 7: Defined thresholds used to calculate the rescaling equation for Ecosystem Pressures.

	PRESSURE THRESHOLDS	
	TN Total Loading	TP Total Loading
SCORE	kg TN estuary km^{-2} yr^{-1}	kg TP estuary km^{-2} yr^{-1}
100	50	25
75	250	50
50	1,000	100
25	3,000	250

Table 3-8: Defined thresholds used to calculate the rescaling equation for Water Quality

	WATER QUALITY THRESHOLDS			
	Temperature	Dissolved Oxygen	Total Nitrogen	Total Phosphorus
SCORE	°C	mg L^{-1}	µg L^{-1}	µg L^{-1}
50	18	10.0	135	10
38	22	9.0	175	13
25	26	7.5	250	22
13	30	4.0	400	40

Table 3-9: Defined thresholds used to calculate the rescaling equation for Light Availability

	LIGHT AVAILABILITY THRESHOLDS					
	% Surface Irradiance Available	Secchi depth	Total suspended solids	Chlorophyll *a*	Macroalgae % cover	Epiphyte biomass per SAV biomass
SCORE	%	cm	mg L^{-1}	µg L^{-1}	%	g epiphyte / g seagrass
50	32	500	10.0	2.5	3	0.25
38	23	400	12.5	3.0	5	0.50
25	19	300	15.0	4.0	8	1.00
13	15	200	17.5	6.0	14	1.50

Table 3-10: Defined thresholds used to calculate the rescaling equation for Seagrass

	SEAGRASS THRESHOLDS				
	Aboveground biomass	Belowground biomass	Shoot density	Percent Cover	Blade length
SCORE	g m^{-2}	g m^{-2}	shoots m^{-2}	%	cm
50	400	800	1910	50	80
38	300	600	1146	25	60
25	200	400	764	10	40
13	100	200	382	5	20

Table 3-11: Defined thresholds used to calculate the rescaling equation for Harmful Algal Blooms (HABS)

	HABS THRESHOLDS
	A. anophagefferens
SCORE	cells mL^{-1}
100	30,000
75	90,000
50	150,000
25	200,000

PAGE 3 (OF TAC COMMENTS TO COMMENTS ON METHODOLOGY)

"The original expectation was to identify thresholds that could be applied to other coastal waters. The selection of thresholds must be clearly documented and transparent. Any limitations on the applicability to other waters should be noted."

- Page 60 of the QAPP notes, "An important goal of this project is to develop an index of ecological condition for the BB- LEH estuary that may be extended to other New Jersey estuaries. This index can be used to assess and define ecological impairment, and hence it will be extremely useful to NJDEP and US EPA estuarine and marine environmental assessment programs." However on page 15 the QAPP also acknowledges "However, estuaries are highly variable in respect to the causes of, and responses to, nutrient enrichment, and therefore site-specific measures of assessment must be applied. This ecosystem-based investigation targets the BB-LEH estuary in New Jersey as a case study."
- Recall the major difference between estuaries (mentioned in the QAPP) and coastal waters (mentioned in the TAC comments). Estuaries are defined as "partly enclosed coastal bodies of water with one or more rivers or streams flowing into them and with a free connection to the open sea". Coastal waters, as defined by the U.S. EPA, are broader in meaning and include estuaries, bays, and U.S. territorial waters from shorelines out to the federal 12-mile limit. As guided by the QAPP, the Index of Eutrophication has been developed for estuaries – not all coastal waters. The Index of Eutrophication cannot be applied to all other coastal waters.

- We note limitations on the applicability to other waters on pages 77 and 212 of the original report. For your convenience we copy the pertinent paragraph here and make it a separate paragraph in the section “Limitations of the Approach” in the chapter regarding index development.
- “Thresholds and rescaling equations have been calibrated for BB-LEH as a coastal lagoon. However, while there may be applicability of these thresholds to other similar coastal lagoons in New Jersey or elsewhere (such as Great South Bay, NY, Chincoteague Bay, MD/VA, Hog Island Bay, VA, etc.), the thresholds established may be of limited utility for other New Jersey waters (e.g. Raritan Bay, NY/NJ Harbor, and Delaware Bay) that do not share important characteristics. BB-LEH is in part extremely susceptible to even small amounts of nutrient loading due to its enclosed geomorphology and slow water circulation and flushing time. In contrast, coastal waters along the Atlantic Coast, Raritan Bay, and NY/NJ Harbor, and Delaware Bay have much quicker and stronger circulation patterns and therefore respond to nutrient enrichment at different time scales. Additionally, while heavy metals, inorganic, and organic toxicants may be important considerations for ecological health in some New Jersey waters, they may be of lower priority for BB-LEH. Toxicological analysis of sediments and the water column are beyond the scope of this project and have not been included in the Index of Eutrophication or its component indices.”
- We cannot apply these thresholds and the Index of Eutrophication to other coastal waters in this project because that is beyond the scope of the QAPP.
- The thresholds selected and the equations used to rescale data into scores for the Index of Eutrophication are clearly documented in tables shown above in this response, and are included in the revision. We have thoroughly documented and justified how we have arrived at these thresholds.

PAGE 3 (OF TAC COMMENTS TO COMMENTS ON METHODOLOGY)

“The report includes several references that were consulted. See: “Ecosystem State: Water Quality (page 78), include the following statements: • Kemp et al. 2004 list statistically derived concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) beyond which submerged aquatic vegetation is not present at a variety of salinity regimes. See Table 3-3. • Wazniak et al. (2007) summarized pertinent thresholds regarding dissolved oxygen, (see Table 3-4) and for total nitrogen, total phosphorus, and chlorophyll a (see Table 3-5) for Maryland’s Coastla Bays. • For BB-LEH, dissolved oxygen thresholds were defined relative to the New Jersey standard of impairment, which is established at 4 mg L^{-1}. Kemp derived DIN and DIP concentrations of 0.15 TN and 0.01 TP which are expressed as median values calculated over the growing season, whereas Wazniak values for TN and TP are annual averages of 0.55 TN and 0.037 TP. Figures 2-1 through 2-7 present the maximum, minimum, and average concentrations by year. However, based on the threshold selected the data should be averaged appropriately and presented. Figure 5-2 presents nitrogen concentrations by seasons. This figure should be revised to be consistent with the threshold selected. If Kemp is the basis, then the figure should be present median concentrations during the growing season. If Wazniak is the basis, then annual averages should be used.”

- We used Wazniak as the basis. Wazniak used annual means, as does this report. Figures 2-1 through 2-7 include annual means, minimum, and maximum. Kemp 2004 is referenced for comparison purposes and to demonstrate the variety of thresholds considered.

- Figure 5-2 presents seasonal information of total nitrogen concentration aggregated at decadal scales and is binned into categories that were determined from the data distribution to emphasize spatial patterns. Data averaged over a decade should not be confused with annual mean data. Note that annual mean total nitrogen concentrations greater than 400 µg L^{-1} receive very low scores. At decadal scales, very little area of BB-LEH has total nitrogen concentrations below 421 µg L^{-1}. This figure as shown in the report is now In Press in Aquatic Botany (as Figure 6). The complete citation is Fertig, B., et al., Changing eelgrass (*Zostera marina* L.) characteristics in a highly eutrophic temperate coastal lagoon. Aquat. Bot. (2012) http://dx.doi.org/10.1016/j.aquabot.2012.09.004. Though caution should be used when comparing decadal means of seasonal data to annual means that include all seasons each year, we revise Figure 5-2 to show these data in comparison to the thresholds selected for annual mean total nitrogen concentrations. In each of the time periods (June-July, August-September, October-November), much of the area of BB-LEH indicates high total nitrogen concentrations that would receive very low annual scores based on the threshold values.

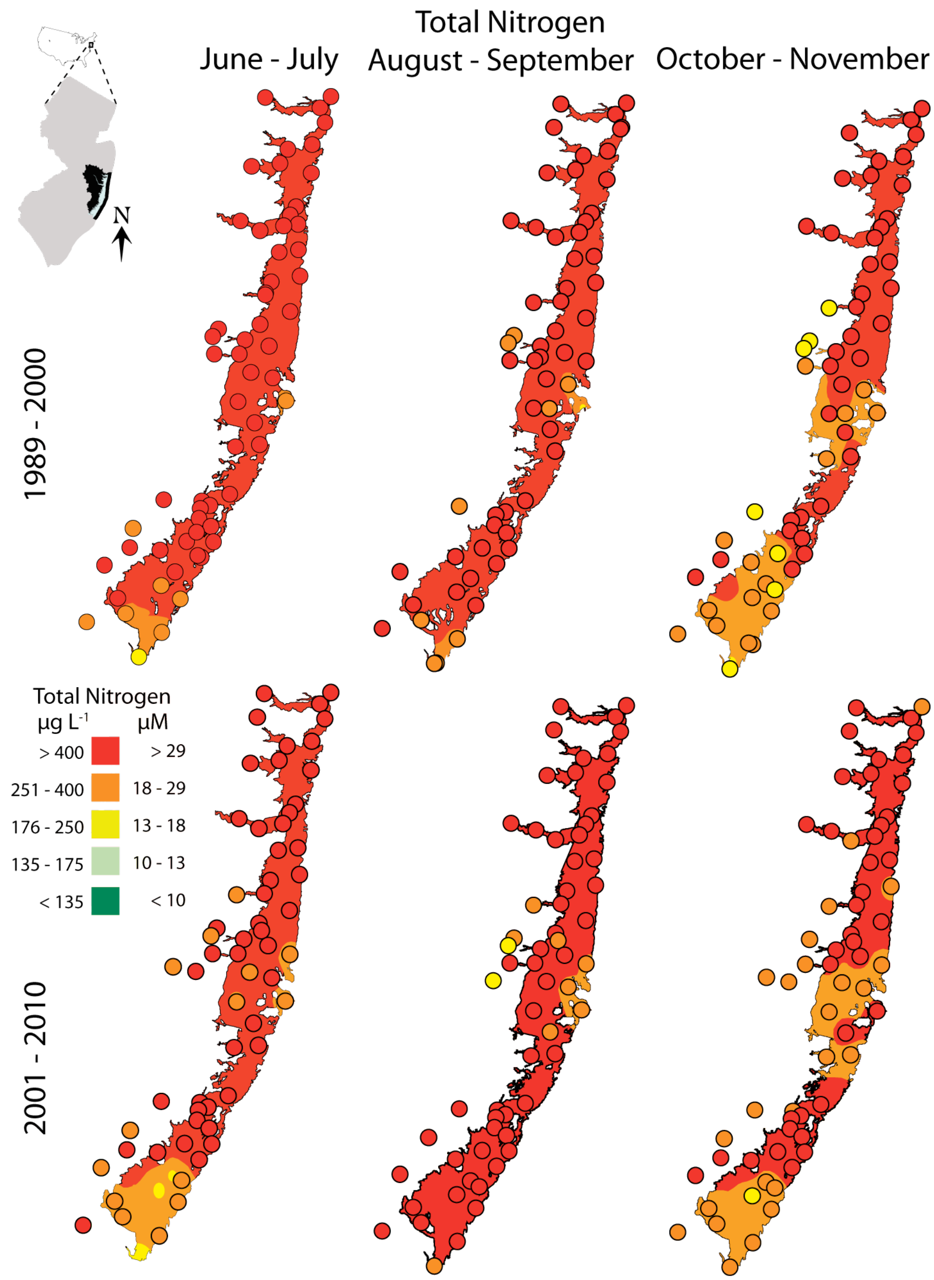

Figure 5-2. Total nitrogen concentrations during June-July (left), September-October (middle), and October-November (right) taken as a decadal mean (1989-2000 on top, 2001-2010 on bottom). Means for each station appear as dots. Interpolation by Inverse Distance Weighting. Data from NJ DEP Bureau of Marine Water Monitoring.

PAGE 3 (OF TAC COMMENTS TO COMMENTS ON METHODOLOGY)
"The adopted water quality criteria for dissolved oxygen were used even though Table 3-4 includes criteria that might be more appropriate for Barnegat Bay. No discussion is provided to establish what indicates the adopted water quality criteria are the appropriate water quality criteria. The DO criteria developed for seagrasses for Maryland Coastal Bays were included but ignored."

- Dissolved oxygen thresholds for Maryland's Coastal Bays were considered for comparison since that is a similar ecosystem in many ways.
- There are, however, several critical differences between Chincoteague Bay and BB-LEH, not the least of which is the availability of data for dissolved oxygen and the methods of collecting this data. Data for assessing ecosystem condition in Maryland are based on databases of 20 stations consisting of long-term fixed stations, continuous monitoring stations with real-time telemetry, continuous monitoring stations without telemetry, and National Data Buoy Center or NOAA buoys. Data from Maryland are available online: http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm
- Recently, we have learned that Maryland is considering looking into modifying their assessment criteria to more closely assess periods of night-time oxygen stress rather than daytime conditions that may mask important times of stress that are currently missed. This analysis requires large quantities of data at high temporal resolution. This level of analysis is, however, beyond the scope of the QAPP and would be difficult to address for BB-LEH due to insufficient quantities of data.
- Dissolved oxygen is well known to exhibit cyclical diel patterns associated with photosynthesis, respiration. Dissolved oxygen is also affected by many factors including temperature, stratification, and processes associated with eutrophication. One implication of these factors is that it is critical to measure dissolved oxygen throughout these cycles and at multiple depths (e.g. surface and bottom across a range of total depths) since shallow areas close to shore may exhibit different conditions than more open or deeper areas of the estuary. Though BB-LEH is well mixed and does not often stratify or exhibit classical two-layer estuarine dynamics, continuous measurements in several different habitat types are recommended to provide a holistic understanding of oxygen dynamics, particularly during nighttime and early morning when the estuary may be more susceptible to oxygen depletion.
- In New Jersey, The Surface Water Quality Standards are developed and administered in conformance with requirements of the Federal Water Pollution Control Act 33 U.S.C. §1251 (also called the Clean Water Act) and the Federal regulatory program established by the USEPA at 40 C.F.R. Part 131. The Surface Water Quality Standards are also developed pursuant to the New Jersey Water Quality Planning Act, N.J.S.A. 58:11A et. seq. and the New Jersey Water Pollution Control Act, N.J.S.A. 58:10A et. Seq Surface Water Quality Standards establish designated uses. The NJ DEP sets the dissolved oxygen, nutrients, and all other standards to assure that they protect the existing and designated uses. In NJ the DO criterion for ocean waters is less than 5 mg/l; for estuarine waters the DO criterion is 4 mg/l. The NJ DEP establishes the water quality monitoring network and sampling methods to measure compliance with Surface Water Quality Standards. The NJ DEP establishes the water quality assessment methods to apply monitoring data to determine if a water body attains the water quality standards or is "impaired".
- Thus, 4 mg L-1, the NJ DEP criterion for dissolved oxygen, is established as a threshold for a very low score and other thresholds are set relative to that minimum.

PAGE 3 (OF TAC COMMENTS TO COMMENTS ON METHODOLOGY)

"The thresholds selected for Light Availability are also unclear. Figure 3-20 identifies several studies with differing maximal depth limits, light attenuation coefficients, and minimal light requirements. Associated light attenuation by various factors such as plankton (chlorophyll a) total suspended solids, and macroalgae are indicated as Kennish et al. 2011 and provided in Table 3-7 but this table describes Area Normalized occurrence of macroalgae. It is necessary to explicitly define which thresholds were selected and on what basis."

- We have clarified the thresholds that are defined for each indicator for the Light Availability component in Table 3-9. This table includes a score for various levels of % surface irradiance available, Secchi depth, total suspended solids, chlorophyll a, macroalgae % cover, and epiphyte biomass per SAV biomass. Note that the main pieces of relevant information in Figure 3-20 showing the maximal depth limits, light attenuation coefficients and minimal light requirements are for the two species of seagrass found in Barnegat Bay-Little Egg Harbor: *Zostera marina* (eelgrass) and *Ruppia maritima* (widgeon grass). Table 3-7, from Kennish et al. 2011 serves as reference with regards to the occurrence of benthic macroalgae blooms and documents that these blooms have occurred frequently and are concerning ecologically. Fertig et al. 2012 conclude that benthic macroalgal shading, in addition to nutrient loading, is an important factor in the changing characteristics of eelgrass populations in Barnegat Bay-Little Egg Harbor.

PAGE 3 (BOTTOM OF PAGE)

"*Component selection incomplete and duplicative; threshold basis not documented; index derivation has weaknesses:* The researcher selected six components to use in describing biotic condition. There is no definition of "eutrophic condition" so the term should be replaced with "biotic condition" as a less cause-based term. As defined, the components consider factors that overlap across component types, which would tend to afford greater importance to those factors. For example, watershed pressure considers TN and TP loading, while water quality considered TN and TP concentration. Light availability factors are dependent to some extent on the water quality factors. To partially alleviate this effect, in the derivation of the overall eutrophication index, the watershed pressure index is not included to avoid conflation of independent and dependent variables. However, other factors, like physical stressors are not considered in the index at all."

- We do not agree that eutrophic condition should be replaced by the term biotic condition. Biotic condition can include a substantially different suite of key indicators and may be affected by a wide variety of factors. The overall objective of this project is to assess eutrophication or eutrophic condition of the estuary. That is the target (see the QAPP for more specifics). The term 'eutrophic condition' refers to the status of eutrophication of the waterbody, and this is part of the title of the report and project (see page 18 of the report for further description). The title of the report is ("Assessment of Nutrient Loading and Eutrophication in Barnegat Bay-Little Egg Harbor, New Jersey in Support of Nutrient Management." The term 'eutrophic condition' can be found on pages 1, 28, 60, and 61 of the QAPP, and the QAPP was signed off and approved by members of the

TAC, including approval of the term 'eutrophic condition'. In this project, we are following all protocols and content of the QAPP verbatim.

- Eutrophication is defined as the process of nutrient enrichment and increase in the rate of organic matter input in a water body leading to an array of cascading changes in ecosystem structure and function such as decreased dissolved oxygen levels, increased microalgal and macroalgal abundance, occurrence of harmful algal blooms (HABs), loss of seagrass habitat, reduced biodiversity, declining fisheries, imbalanced food webs, altered biogeochemical cycling, and diminished ecosystem services. This definition is widely accepted and used in practice. We include this definition in the report on pages 16, 28, and 107.
- TN and TP loading, which occur in the watershed, are different factors than TN and TP concentrations measured in the water column. Nutrient loading has many possible fates, for example sequestration in soils or sediments, release to the atmosphere, recycling through microbial, food web, and other biotic cycles, transport and circulation among ecosystems (e.g. terrestrial to freshwater to estuarine to oceanic), etc. TN and TP concentrations in the estuarine water column reflect the portion of the loading that has entered the estuary in dissolved or particulate form and remains at the time of sampling.

PAGE 3-4 (OF TAC COMMENTS TO COMMENTS ON METHODOLOGY)

"These other factors may be difficult or impossible to consider at this time, perhaps due to lack of data or lack of complete understanding regarding thresholds of effect. They may include community make up of algae, effect of entrainment/impingement in the Oyster Creek cooling water system and from extensive watercraft traffic, and the effects of resource harvest (has it been/ is it at sustainable levels?). Only presence or absence of HABs are considered in the index, even though it is acknowledged that greater dominance of pico algal forms is likely to negatively impact clams. Failure to consider other relevant stressors increases the uncertainty of the findings and these uncertainties should be discussed. As stated, design of an effective management response depends on identifying the suite of significant stressors and determining the relative importance and role in cause and effect relationships with the biotic response indicators of concern."

- The QAPP states on page 28: "This project will determine estuarine biotic responses to the loading of nutrients across a gradient of upland watershed development and associated estuarine nitrogen loading, and identify key biotic responses across a variety of estuarine organisms by examining shifts in phytoplankton, benthic macroalgae, seagrass, epiphytes, benthic invertebrates, and shellfish structure."
- The TAC lists a number of potential anthropogenic effects and factors. However, the assessment of many of these are beyond the scope of the project as stated in the QAPP and/or are not relevant regarding the stated objectives of the project regarding eutrophication and biotic condition assessment with respect to supporting nutrient management planning. This project cannot assess factors not included in the QAPP and must focus on factors that are directly relevant to eutrophication and/or nutrient management.

- Algal community composition is not within the scope of the QAPP. Chlorophyll a is addressed to as a proxy for phytoplankton abundance. This is standard, accepted, and widely used.
- Effect of entrainment/impingement in the Oyster Creek cooling water system is not within the scope of the QAPP. Entrainment/impingement is not relevant regarding eutrophication or support of nutrient management planning.
- Assessing effects of watercraft traffic is beyond the scope of the QAPP. Watercraft are not relevant to discussions of eutrophication.
- Effects of resource harvest, the quantification of sustainable yields, and comparison of harvest levels vs. ecosystem capacity are beyond the scope of the QAPP.
- The TAC misstates the consideration of HABs by the index. Concentrations of *Aureococcus anophagefferens* cells – rather than merely presence/absence – are considered by the Eutrophication Index. Thresholds of *A. anophagefferens* are listed in Table 3-11.
- Biotic conditions may respond to a wide range of stressors. However, the various potential stressors listed that are not included in the QAPP and are not directly relevant to eutrophication and/or nutrient management cannot be assessed. Including factors irrelevant to eutrophication would actually increase uncertainty and confusion regarding findings. Therefore, the factors stated above cannot be discussed.

PAGE 4 (OF TAC COMMENTS TO COMMENTS ON METHODOLOGY)

"To develop the index, the study relies on existing data supplemented for some factors by new data collection. Raw data for each factor are provided, not including the more recent data collected through the intensive Barnegat Bay study, which was beyond the SOW. For many years within the span of the study, there is little or no data on clams and benthic organisms. SAV data are sporadic. Only water quality data are generally available. Thresholds are selected for each factor to associate with assessments of highly degraded, poor, moderate, good, excellent. Given the methodology used to derive a unit-less score for the index, the index assessment for any given year is opportunistic (limited by the data available for a given year) and not deterministic (informed by data from the full suite of prospective relevant factors). As a result, the importance of setting thresholds against which observations are compared to determine the assessment cannot be overstated. As the value for each threshold is one of the most important elements in determining the outcome of applying the index, it is essential that the threshold values be solidly based in science. A key requirement expressed as part of earlier reviews of interim products was that the specific basis for selecting thresholds should be identified and substantiated. Instead, only a generic description of the types of sources used for selecting thresholds was provided. This deficiency must be addressed to allow a complete assessment of the tool."

- This project is the most comprehensive, holistic assessment of Barnegat Bay-Little Egg Harbor to date. It achieves this by assembling and assessing multiple large datasets that were originally collected at various times and places that were often misaligned since each dataset was collected and designed based on meeting independent goals for various purposes. This does not reflect inadequacies on the part of either the initial projects that resulted in the datasets and does not reflect inadequacies of this project, but rather merely reflects that various needs are being met over time by a variety of projects. One important result of the assembly of this database and the current project is the identification of a set of indicators that, if monitored at appropriate temporal and spatial scales, will be able to provide a holistic dataset regarding eutrophication condition of Barnegat Bay-Little Egg Harbor. Thus, while assessment of a given historical year may be opportunistic based upon data availability, assessments conducted in the future by applying this Eutrophication Index has the potential to be deterministic if monitoring is thoroughly conducted on the full suite of indicators at appropriate spatial and temporal scales.

- Consideration of monitoring design is critically important to gathering holistic data on Barnegat Bay-Little Egg Harbor. Benthic surveys of clams or other invertebrates may be difficult to interpret without sufficient temporal resolution. Even if statistically significant changes are observed between the 2001 dataset and data collected in 2012-2013, interpretation of changes and attributing or assigning causes for changes may be difficult with only two or three time points that have sufficient spatial resolution (given the heterogeneity of the benthic habitats) in this coastal lagoon. Seagrass data begin to be regularly available in 2004, but do not extend back far enough in time to document the inception of biomass declines. Water quality data – though available at numerous locations in the estuary and generally available over the long term, were not monitored at time intervals matching natural variability of the indicators. In the future, though, as awareness increases regarding the monitoring needs for identifying a holistic dataset of Barnegat Bay-Little Egg Harbor and as resources become available to execute effective monitoring designs over the long-term, the data availability will improve and shift from opportunistic to deterministic.
- We agree that threshold definition is of upmost importance for the Eutrophication Index. This is true regardless of the quantity of data available. The thresholds we define are solidly based in science. We have clarified the definition of these thresholds for each indicator by including several tables that list thresholds for each indicator in addition to the equations used for rescaling data into the unit-less score.

PAGE 4 OF THE TAC COMMENTS (COMMENTS ON METHODOLOGY)

"Determination of index values blends raw scores (comparison of average of raw data to a selected threshold) and weighted scores (square of eigenvector value, considering the factors for which there was data in a given year). Weighted scores simply represent a measure of the variability of the factor, if it is present within a given year. If there is no data, the factor is given no weight. The purpose of blending the weighted score with the raw score is unclear. Supporting basis for the statistical approach is needed. Again, because the index score depends entirely on the selected threshold, the basis for selecting thresholds must be thoroughly documented and justified. For the overall index, depending on data availability for various factors, the index may be derived from one or two factors. This is particularly problematic because, as previously stated, there has been no demonstration that the factors selected are the only (or even the most important) factors responsible for the biotic condition."

- Yes, the index weights indicators so as to be able to handle temporal or spatial gaps in the data record. The purpose of adding the Raw Score and the Weighted Score to arrive at the Final Score for an Indicator and each component index (e.g. Water Quality Index, Light Availability Index, Seagrass Response Index) is to assess both the condition and consistency of each indicator and each index. Note the important difference between the *weighting* and the *Weighted Score*. The *weighting* is the square of the eigenvector and represents the variability of the factor if data are available in a given segment in a given year. The *Weighted Score* is the Raw Score multiplied by the weighting and thus represents the *consistency of the condition for that indicator*. Weighted scores provide a measure of the consistency of the observations with respect to thresholds for the appropriate indicator. Consistency is important to include in an Index of Eutrophication because it highlights times and places when and where conditions of each indicator are changing (either positively or negatively) so that these indicators can be targeted for attention (e.g. for monitoring, management, or research). The implications for this are that this tool can help prioritize decisions regarding limited resources available for various actions. For example, if an indicator is in flux, it may be worthy of more intense monitoring, research, or remediation action. If that same indicator consistently exhibited an extreme conditions (e.g. 'Excellent' or 'Highly Degraded') discussions regarding prioritization of resources may be efficiently directed towards another indicator.

- Thresholds for each indicator are clearly stated in tables and the justification for each threshold for each indicator is thoroughly documented. Detailed figures and tables from the literature are included through Chapter 3.
- We are not sure what the TAC means by 'the index may be derived from one or two factors'. As clearly shown in Table 3-2 there is no year in which the Index of Eutrophication is based on only one or two indicators. There are no data available during 1992 (except nutrient loading) and the Index of Eutrophication is not calculated for that year. During 1989-1997 (excepting 1992), when the Index of Eutrophication is essentially the same thing as the Water Quality Index (since insufficient Light Availability and Seagrass data are available, see Table 3-15), there are three indicators that are used: temperature, dissolved oxygen, and total nitrogen concentration (total phosphorus concentration did not begin to be monitored until 1999).
- As specified and required in the QAPP, the Index of Eutrophication is a tool for assessing the condition and status of eutrophication in BB-LEH. Eutrophication condition is not the same thing as biotic condition, as the latter is much broader in scope. The factors included in the Index of Eutrophication have been specified in the QAPP and other factors not included in the QAPP are outside the scope of this project. Identifying and demonstrating all the (or even the most important) factors responsible for biotic condition are outside the scope of the QAPP and the project.

Page 4 of the TAC Comments (Comments on the Statistical Approach)

First bullet: "The NOAA ASSETS approach that was specified in the QAPP was not followed. It was fine that an additional approach, the use of PCA, was evaluated, but the original approach also should have been pursued or an amendment to the QAPP sought. The TAC has been continuously asking for additional information as to whether the PCA is appropriate in this case and we find this report still does not provide the necessary detail to evaluate its use."

- The only reference in the QAPP to the NOAA ASSETS approach is on page 60 (emphasis added here): "The **basic methodology** used in the National Estuarine Eutrophication Assessment (NEEA) model will be applied to develop a biotic index of eutrophic condition for the estuary (Bricker et al., 1999, 2007). For the period from 2004 to 2011, the NEEA model of Bricker will be applied to the water quality and biotic data collected to **compare against the findings of Bricker** et al. (1999, 2007) for previous years to determine if any change in eutrophic condition has occurred. However, the approach used in this project will entail **dividing the estuary into three segments** based on environmental gradients. A **wider array of biotic indicators** will also be used because more key biotic parameters have been measured in this project. A **numeric scoring system** will then be used that computes an index value from key water quality and biotic indicator measurements in each of the three estuary segments."

- The **basic methodology** used in the NEEA model has been conducted for this approach. This has been specified on pages 69 of the final project report in the section titled "Introduction: Building on the National Estuarine Eutrophication Assessment". This section details the methodology of the NOAA ASSETS approach and the modifications of it conducted by this project.
- As described in the QAPP and the final report, this project divides Barnegat Bay-Little Egg Harbor into **three segments** and computes index values for each of these segments. The justification for this has been described in the final report, progress reports and project presentations.
- As described in the QAPP and the final report, **a wider array of indicators** has been used, as discussed in Component 3 of the final report.
- As described in the QAPP and the final report, a **numeric scoring system** is used to compute the Index of Eutrophication.
- We **compare our findings against those of Bricker** et al. (1999, 2007) by adding the relevant figure from Bricker's NEEA report and comparing our results from 2007. Further, to identify if there have been changes in the eutrophication condition; we compare our results from 2007 to those of 1999 (the years of the NEEA report). We add this information to Component 4 as a separate section as shown below.
- The approach of this report is validated by obtaining similar results to that of an different, independent study (i.e. the NEEA report).

Validation Against the National Estuarine Eutrophication Assessment

The National Estuarine Eutrophication Assessment (NEEA) previously analyzed the condition of Barnegat Bay-Little Egg Harbor (Bricker et al. 1999, 2007). Methods for the NEEA approach are described in the section of Component 3 'Building on the National Estuarine Eutrophication Assessment'. Here, we compare our results from 2007 to findings from the NEEA report as a validation of the Index of Eutrophication that we developed in this study.

The 2007 NEEA report documents that Barnegat Bay-Little Egg Harbor had 'High Overall Eutrophic Condition' (Figure 4-1, from Bricker et al. 2007). This conclusion was reached because both primary symptoms (chlorophyll *a* and macroalgae) had high expression levels of eutrophication, and the highest secondary symptom (harmful algal blooms) also had high expression levels of eutrophication. These symptoms of eutrophication are shown visually in a conceptual diagram (Figure 4-2, from Bricker et al. 2007).

Our findings from 2007 show that the Index of Eutrophication score in the North was 41, in the Central segment was 43, and was 52 in the South segment (Figure 3-39). Thus, the overall eutrophication status in BB-LEH was considered ‘Moderate’ in 2007 for each of these three regions.

The condition of BB-LEH deteriorated over time in the Central and South and remained relatively constant in the North. This project reports a 1999 Index of Eutrophication score of 42 in the North, 65 in the Central, and 57 in the South (Figure 3-39). These values of the Index of Eutrophication are ‘Moderate’ for the North and South. The 1997 value of the Index of Eutrophication in the Central Segment is ‘Good’. The numerical difference over time is important however.

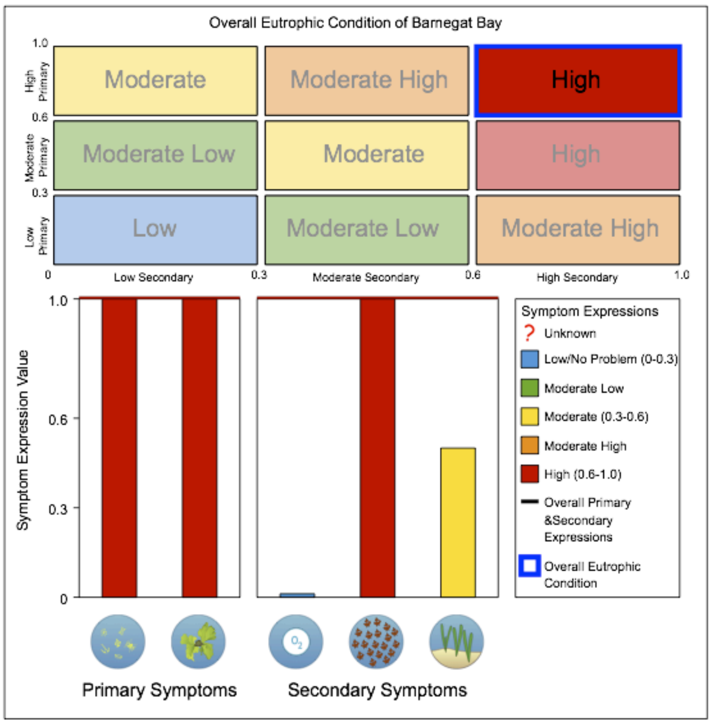

Figure 4-1

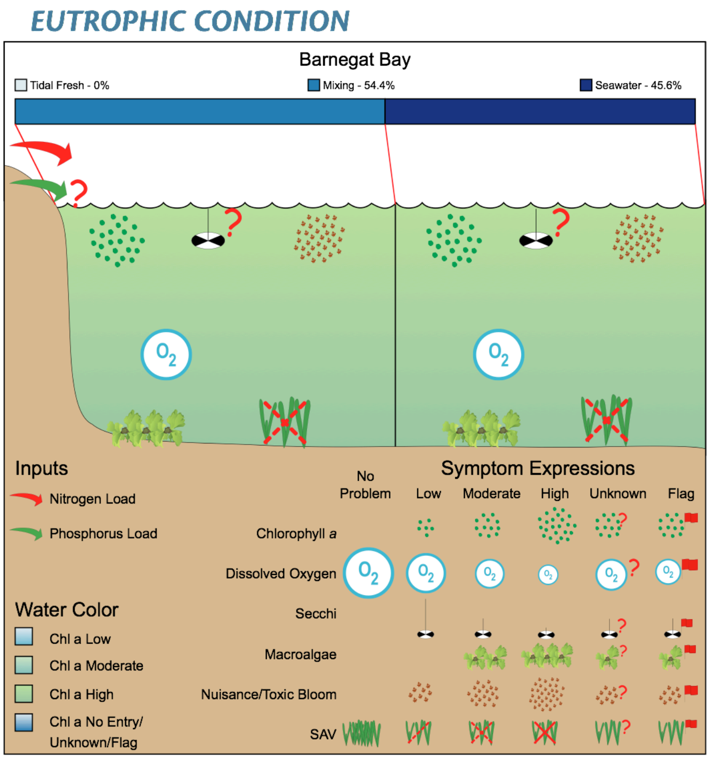

Figure 4-2

Page 4 of the TAC Comments (Comments on the Statistical Approach)
Third bullet: "The summary tables present minimal information. Since there are non-detects, skewness, and possibly other issues of concern, more thorough summary tables should be presented. They should include the number of non-detects and information on the distribution of the detection limits. Some comments on outliers and skewness should also be included in the table discussion."

- The summary tables are presented to provide summary information. The large quantity of data analyzed for this project renders impractical the inclusion of the raw data within this report. However the files for the data are available for download by the TAC.

Page 5 of the TAC Comments (Comments on the Statistical Approach)
Fourth bullet: "On page 67 mention is made of zero values in the data. Are these non-detects? The treatment of non-detects needs to be discussed for all analyses in this report, including PCA, Regression, Correlation and ANOVA."

- Zero values in the data are not mentioned on page 67 (original report) though perhaps the TAC was referring to QA/QC protocols adhered to during the database assembly, which is discussed on page 63. If so, the passage in question refers to ensuring that the data were handled correctly by the statistical software, rather than assurances regarding the measurements themselves (i.e. non-detects). Different software packages handle data entry and data importation differently (e.g. allowing empty cells, entering a '.' or 'NA' for empty cells, etc.). It is critical to ensure that missing data are appropriately distinguished from observations of 0 in the statistical software packages. Missing data are not non-detects since no attempt at detection has been made. Zero values are not necessarily non-detects. For instance, percent cover of seagrass or macroalgae in a given quadrat may be 0% for an individual observation. In this instance, this value should not be treated as a non-detect because the visual estimation has sufficient power to correctly determine this value.

Page 5 of the TAC Comments (Comments on the Statistical Approach)
Fifth bullet: "The approach taken in using PCA (pg. 18) in this report is not standard and no documentation is presented to justify it. Typically, to develop an index using PCA, the scores of the first few principal components would be examined. If the first eigenvalue (score variance) comprises a large amount of the total variability, then the first principal component might be taken as the index. If weighting the index is desired then the first eigenvalue would be used as a weight. In this report, there do not seem to be any attempts to assess the adequacy of using only the first principal component."

- The PCA approach represents an innovative and novel method for development of a Index of Eutrophication that can handle analysis of databases that aggregate data. It is capable of handing data that are misaligned and (in some cases) missing altogether. This is a powerful new approach. In addition to review by the TAC, it is subject to peer-review by the scientific community and is thus being thoroughly vetted as a justified and documented approach for assessing eutrophication in Barnegat Bay-Little Egg Harbor.
- For each PCA conducted, scree plots of all principal component axes have been examined. As is generally the case, the first principal component generally represents ~50-75% of the variation and the first two axes cumulatively represent ~80-90% of the variation. We note this in the text. Further, we specify that the square of the first eigenvector has been used to calculate the weighting for each respective PCA.

Page 5 of the TAC Comments (Comments on the Statistical Approach)
Sixth bullet: "The approach taken in this report is to use the squared component of the eigenvector as a multiplicative weight for that component of the index. The justification is that this weight would be the variance of the component. This claim is not correct. If the variables had been standardized to a variance of 1, then there would be some basis for this, although correlations between variables would also have to be considered. The SAS code in the appendices shows that no variance standardization was done during the PCA analysis and it did not appear to have been done before that. The use of multiplicative weighting should be justified as well as this particular weighting method."

- First off, rescaling indicator observations into the Raw Score standardizes the scales and brings all indicators into the same order of magnitude and same range of values. These indicators now range from 0 to 50 for each indicator (whereas the values of the observations have different ranges, often at different orders of magnitude). So while the variance of the Raw Scores is not equal to 1, it is homogeneous between indicators.
- Second, the PCA analysis is conducted on these Raw Scores, not the observations of the indicators. This means that the weighting that is computed based on the eigenvector calculated from the PCA has been conducted on variables with homogenous variances.
- Third, the SAS code does indeed include variance standardization with the inclusion of the option "covariance" in the Proc princomp statement. The covariance option computes the principal components from the covariance matrix. If you omit the covariance option,

the correlation matrix is analyzed. Note that use of the covariance option causes variables with large variances to be more strongly associated with components with large eigenvalues and causes variables with small variances to be more strongly associated with components with small eigenvalues. Therefore, the covariance option should not be specified unless the units in which the variables measured are comparable or the variables are standardized in some way. As indicated above, the units of the variables (i.e. the Raw Scores) are indeed comparable and have been standardized via the rescaling equations to result in homogeneity of variance.

- Further, since the PCA was conducted n the covariance matrix rather than the correlation matrix, the intention of the concern of the reviewer has been addressed – though the reviewer incorrectly noted the consideration of correlations. Correlations are addressed by default in a PCA by computing the principal components from the correlation matrix, as indicated above.
- In the report, we remove the phrase regarding the weighting as the variance of the component.

Page 5 of the TAC Comments (Comments on the Statistical Approach)

Seventh bullet: "The only justification for combining the weighted and raw indices is given on page 78. This states that it integrates the multiple indicators and their variability. The advantage of this approach is not obvious and requires some justification and documentation. Combining the two indices might serve to blur any useful measure rather than improve it."

- The advantage and justification of this approach is elaborated on. As before, we report Raw Scores and Weighted Scores for indicators and components for documentation in addition to the Index scores for each component and the Index of Eutrophication. This way, the information at all steps is available for perusal.
- The purpose of adding the Raw Score and the Weighted Score to arrive at the Final Score for an Indicator and each component index (e.g. Water Quality Index, Light Availability Index, Seagrass Response Index) is to assess both the condition and consistency of each indicator and each index. Note the important difference between the <u>*weighting*</u> and the <u>*Weighted Score*</u>. The <u>*weighting*</u> is the square of the eigenvector and represents the variability of the factor if data are available in a given segment in a given year. The <u>*Weighted Score*</u> is the Raw Score multiplied by the weighting and thus represents the *consistency of the condition for that indicator*. Weighted scores provide a measure of the consistency of the observations with respect to thresholds for the appropriate indicator. Consistency is important to include in an Index of Eutrophication because it highlights times and places when and where conditions of each indicator are changing (either positively or negatively) so that these indicators can be targeted for attention (e.g. for monitoring, management, or research). This can help prioritize decisions regarding limited resources available for various actions. For example, if an indicator is in flux, it may be worthy of more intense monitoring, research, or remediation action. If that same indicator consistently exhibited an extreme conditions (e.g. 'Excellent' or 'Highly Degraded') discussions regarding prioritization of resources may be efficiently directed towards another indicator.

Page 5 of the TAC Comments (Comments on the Statistical Approach)
Eighth bullet: "The PCAs were performed on one to three variables (pg. 369). A PCA on one variable provides no information and should not be included."

- PCA analysis has not been conducted on one variable. The TAC correctly notes that this would be meaningless. To calculate the Index of Eutrophication we average the component indices that are available during each time period. During 1989-1997 only the Water Quality Index is available and so it is weighted 100% and is equivalent to the Index of Eutrophication during those years. During 1998-2003 both the Water Quality Index and the Light Availability Index are available and are each weighted 50% of the Index of Eutrophication. During 2004-2010 the Water Quality Index, the Light Availability Index, and the Seagrass Response Index are available and are each weighted 33% of the Index of Eutrophication. These weightings are shown in Table 3-10 of the original submission (now Table 3-15), which is copied here for your convenience.

Component	Years	Variable	Weighting
Watershed Pressures	1989-2010	Total Nitrogen Loading	0.50
Watershed Pressures	1989-2010	Total Phosphorus Loading	0.50
Water Quality	1989-1999	Temperature	0.66
Water Quality	1989-1999	Dissolved Oxygen	0.33
Water Quality	1989-1999	Total Nitrogen	0.02
Water Quality	1989-1999	Total Phosphorus	0.00
Water Quality	2000-2010	Temperature	0.15
Water Quality	2000-2010	Dissolved Oxygen	0.08
Water Quality	2000-2010	Total Nitrogen	0.13
Water Quality	2000-2010	Total Phosphorus	0.64
Light Availability	1998-2010	Chlorophyll a	0.02
Light Availability	1998-2010	TSS	0.32
Light Availability	1998-2010	Secchi depth	0.04
Light Availability	1998-2010	Epiphyte : Seagrass	0.30
Light Availability	1998-2010	Macroalgae % Cover	0.00
Light Availability	1998-2010	% Light reaching seagrass	0.31
Seagrass	2004-2010	Aboveground biomass	0.08
Seagrass	2004-2010	Belowground biomass	0.02
Seagrass	2004-2010	Shoot density	0.01
Seagrass	2004-2010	Percent cover	0.53
Seagrass	2004-2010	Blade length	0.35
Harmful algae	various	Cell concentration	1.00
Eutrophication	1989-1997	Water Quality	1.00
Eutrophication	1998-2003	Water Quality	0.50
Eutrophication	1998-2003	Light Availability	0.50
Eutrophication	2004-2010	Water Quality	0.33
Eutrophication	2004-2010	Light Availability	0.33
Eutrophication	2004-2010	Seagrass	0.33

Table 3-15 Weightings used to calculate Weighted Scores for indicators in each component and

for each component within the overall Index of Eutrophication Condition.

Page 5 of the TAC Comments (Comments on the Statistical Approach)
Ninth bullet: "The variables have large coefficients of variation, indicating skewness or some large outliers. Since the eigenvectors in a PCA will be influenced by this, the skewness and outliers should be studied and possibly remedied by transformations."

- It is not clear which variables the TAC refers to here. Observations of indicator variables are rescaled into a common, unitless dimension (the Raw Score) that ranges from 0 to 50 according to the equations shown in Table 3-2 of the original submission. The exceptions to this are the Watershed Pressures and the Harmful Algal Blooms, which are rescaled to 0 to 100 because there are not enough indicator variables for a principal component analysis to be meaningful. Observations above or below noted values in the table are censored at the maximum or minimum values of this dimension (50 or 0, respectively for Water Quality, Light Availability, and Seagrass indicators, and 100 or 0, respectively for Watershed Pressures and Harmful Algal Bloom indicators). All PCAs are conducted on this unitless dimension (the Raw Score). PCAs are not conducted on the original indicator variables. Thus, the TAC statement regarding the eigenvectors is incorrect, and no transformations are required.

Page 5 of the TAC Comments (Comments on the Statistical Approach)
Tenth bullet: "On page 185 some regressions are discussed. They all have very low R2 . Even though some of these are significant, it would call for a careful examination of the data to determine whether the regression relationship is valid. Residual plots should be presented to look for deviations from a linear fit."

- To be clear, page 185 (original report) includes Table 2-4 showing correlation analysis between macroalgae areal percent cover and water quality, eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) during three time periods over 2004-2010. It is possible that the TAC was referring to Table 2-3 on page 184 which includes regression analysis of macroalgae areal percent cover over 2004-2010 during three time periods and over the three time periods for each year. In any case, both Table 2-3 and Table 2-4 have already been published as valid, scientifically sound empirical relationships (Kennish et al. 2011). Chi square analysis has shown that occurrences of macroalgae blooms at various levels of percent cover have significantly increased in frequency during 2008-2010 vs 2004-2006 (Fertig et al. 2012). We add an additional figure from this latter publication to clearly illustrate this trend.
- We note: "Macroalgae 'Early Blooms' (70–80%) occurred twice during 2004–2006 and 17 times during 2008–2010 (chi square $p < 0.01$). Macroalgae 'Full Blooms' (>80%) occurred 12 times during 2004–2006 and 24 times during 2008–2010 (chi square $p < 0.05$),"

Fertig, B., Kennish, M.J., Sakowicz, G.P. 2012. Changing eelgrass characteristics in a highly eutrophic temperate coastal lagoon. Aquatic Botany. DOI: http://dx.doi.org/10.1016/j.aquabot.2012.09.004

Kennish, M. J., B. M. Fertig, and G. P. Sakowicz. 2011. Benthic macroalgal blooms as an indicator of system eutrophy in the Barnegat Bay-Little Egg Harbor Estuary. *Bulletin of the New Jersey Academy of Science,* 57: 1-5.

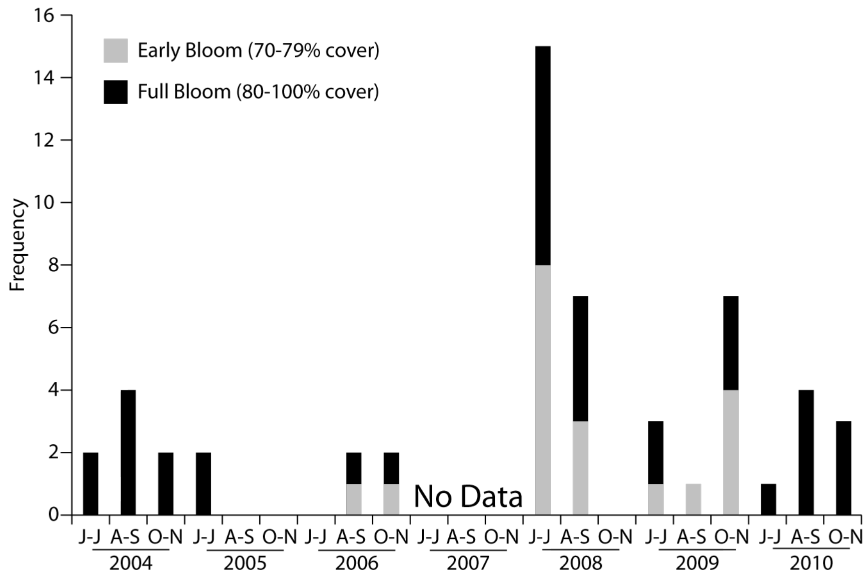

Figure 2- 10 Frequency of macroalgae cover at ‘Early Bloom’ = 70–79%, and ‘Full Bloom’ = > 80% conditions.

Page 5 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
“There are no key findings related to the USGS part of the report including the fact that lawn turf represented about 25% of the developed land area and represent a significant source of nutrients to the bay. The USGS data is an important study on its own, as it demonstrates the spatial and temporal variation of nutrient loads to north, central and southern regions of the Barnegat Bay – Manahawkin Bay - Little Egg Harbor estuary. This information is extremely important for developing watershed specific nutrient management plans for the future.”

- Key Findings related to the UGSS part of the report have been included. For example, the role that turf plays as a portion of developed land area and as a source of nutrients to the estuary are included. Spatial and temporal variations are summarized in the Key Findings.

PAGE 5 (BOTTOM OF PAGE)

“Statements are made throughout the report that seem to represent opinion and are not supported with citations. For example, on page 24 and 91 both state “Point source impacts of the OCNGS…significantly increase mortality of estuarine and marine organisms that inhabit the estuary.”

Impacts of the OCNGS are irrelevant to the development of an Index of Eutrophication and index calculations. It is beyond the scope of this project and the QAPP.

Despite the lack of relevance of OCNGS impacts to the scope of the project (i.e., development of an Index of Eutrophication), we can add here that operation of the OCNGS has, in fact, significantly increased mortality of many species of organisms that also inhabit Barnegat Bay-Little Egg Harbor due to heat and cold shock mortality, impingement and entrainment, and biocidal releases. Impingement and entrainment cause increased mortality of organisms that also inhabit the estuary above that incurred via natural mortality. The absolute numbers of fish, shellfish, invertebrates, and algal species (that inhabit the estuary) lost due to operation of the OCNGS have been recorded by periodic monitoring programs. These losses are well chronicled and documented (e.g., JCPL, 1978; EA, 1986; Kennish et al., 1984; Kennish, 2001).
Citations have been added.

Key Citations on the OCNGS:

Ecological Analysts. 1986. Entrainment and impingment studies at Oyster Creek Nuclear Generating Station 1984-1985. Technical Report, EA Engineering, Science, and Technology, Sparks, Maryland.

JCPL. 1978. Oyster Creek and Forked River Nuclear Generating Stations 316 (a) and (b) Demonstration, Volumes 1-5. Technical Reports, Jersey Central Power and Light Company, Morristown, New Jersey.

Kennish, M. J., M. B. Roche, and T. R. Tatham. 1984. Anthropogenic effects on aquatic communities. Pp. 318-338 in M. J. Kennish and R. A. Lutz, eds., *Ecology of Barnegat Bay, New Jersey*. Springer-Verlag, New York.

Kennish, M. J. 2001. State of the estuary and watershed: an overview. *Journal of Coastal Research*, Special Issue 32: 243-273.

Statements regarding impacts of sea nettle occurrence and macroalgal blooms have been revised.

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"The new land use and nutrient loading information generated for this report appear solid; we must make better use of them in developing the overall conclusions of this study. Taken together, the two pieces (land use and loads) provide a strong argument that the nutrients in the system are from the developed landscape and that more actions must be taken to address nutrient delivery from the developed landscape."

- The Key Findings are revised to more clearly summarize the conclusions regarding land use and nutrient loading information generated for this study and report. We agree that these two pieces of information indicate that nutrients in the estuary are derived and delivered from the developed landscape and that more actions must be taken to address nutrient delivery from the developed landscape.

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"However, there are some troubling inconsistencies in this report. Perhaps most alarming, the bay is reported to exhibit "an insidious system-wide decline" yet the study's findings point out that the different segments and components of the system exhibit distinct patterns and trends,

some of which may even be improving. How do we resolve this inconsistency? First, we must make certain that we identify the weaknesses of the study, which makes use of many different data."

- Despite the limitations of the existing database, which we readily acknowledge, we are confident that the statements made in this report are as accurate as possible. Big picture statements are made with the acknowledgement of the database upon which they rely. We have carefully considered the statements that are made at both the segment and estuary-wide scales.

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"Do we have a handle of the drivers of the bay's eutrophication? Contrary to the author's claim, Guo and Psuty 2000 and Guo et al 2004 suggest that the nearshore coastal ocean, which receives considerable secondary sewage effluent discharges, may be serving as a considerable source of nutrients to the system. The study's conclusions must more clearly identify the weaknesses of the study, which relied primarily on other sources of data. Are we comfortable with the assessment of the eutrophication in the middle bay, which has less developed landscape, is close to the Barnegat Inlet and thus should have better flushing (or is it getting an unrecognized influx of nutrients?), and an "unassessed" potential driver of eutrophication (OCNGS). The authors define eutrophication slightly differently than others; this possibly confuses readers regarding study approaches, causes and effects."

- Figure 3-39 and Figure 3-40 indicate that indeed, we do have a hand on the drivers of the bay's eutrophication and that nutrient loading initially leads to rapid ecological degradation followed by another, degraded ecological state.
- Guo and Psuty (2000) and Guo et al. (2004) do not provide data that measures or confirms entry of the treated sewage wastewaters into Barnegat Bay via Barnegat Inlet. This TAC comment does not provide any actual measurement or concentration of nutrients entering the estuary that are derived from these wastewaters or from ocean waters in general. It also does not mention that the areas where the wastewaters discharge to the nearshore ocean are located 8-10 miles north and south of the inlet and hence are subject to great volumes of dilution.
- Please note, nitrogen data collected by the NJDEP at stations A47A and 169IE near the inlet do not indicate elevated measurements that would be expected if nitrogen was entering the bay from the nearshore ocean through the inlet.
- We have analyzed a significant database on the source and exit point of nitrogen in the Barnegat Bay system using NJDEP water quality data. The results are shown below which is contrary to the TAC statements made above. More specifically, we examined the total nitrogen concentrations in water samples collected by the NJDEP over a ~10-year period at six NJDEP water quality monitoring stations, two in lower Toms River, one just south of Toms River, two in the bay just inside of Barnegat Inlet and one in the nearshore ocean near the inlet (see figure below). These water quality sampling stations were chosen to track the transport of nitrogen and the likely direction of nitrogen movement: either exiting or entering the bay. Box plots showing the results of the nitrogen analysis at these six stations are also given below, which clearly illustrate the likely source (Toms River) and exit point (Barnegat Inlet) of nitrogen in this system. These results are consistent with the USGS findings regarding nitrogen loading which

indicate that Toms River is the major source of nitrogen entering Barnegat Bay. They also reveal that the inlet is the outwelling site for the nitrogen, not the site of major nitrogen entry from the coastal ocean.

- Box plots showing concentrations of total nitrogen measured at six water quality sampling stations by the New Jersey Department of Environmental Protection over the period from 1995 to 2005. See figure above for station locations in Toms River, Barnegat Bay, and the nearshore ocean.
- For evidence supporting these statements, please refer to figures included in the response to the second bullet on page 12 of the TAC comments that refer to page 30 of the report.

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"The report includes too many statements that appear to be opinion or are not supported adequately by citations or presented evidence. The management section does not adequately recognize the weaknesses in the project (the inconsistent data from many sources and other unknown components), and should have made better use of the USGS component to more emphatically indicate the need for corrective land use actions. I would also appreciate better attention to citing other sources appropriately."

- We have taken care to avoid opinion statements in this report. We objectively state the approach, results, conclusions, key findings, limitations, and implications of this report based on the scientific evidence available and the analysis that was conducted while not overstepping or expanding the scope of this project, as specified in the QAPP.
- We have thoroughly documented the data availability and weaknesses of the datasets that this project draws upon. Repetition of this information in the management section is considered redundant. We do include a management recommendation to identify the spatial and temporal requirements for holistically monitoring indicator variables considered critical for future assessments of eutrophication. Additionally, we note that if, for future projects, characterization of overall biotic condition is desired it is important to identify *a priori* all potential impacts including physical and human-derived that may be important drivers.
- We more thoroughly integrate the results of the USGS component in the management recommendations section.
- We have carefully and thoroughly cited appropriate sources throughout the document adding additional references where necessary.

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"The development of the biotic index part of this study should be described and the limitations to the outputs and scores listed. Ultimately this part of the project was a modeling study meant to make more quantitative a subjective NOAA model (ASSETS). The results presented exclude the serious caveats listed in the body of the report as to the Index's poor predictability at times due to uneven datasets (some years have no data for some variables) and how these affect model outputs. The researchers themselves state this reduces the applicability of the index. The more important point in the Key Findings section should be the accuracy and predictability of the model."

- The development and approach of the Index of Eutrophication is detailed in Component 3.
- The limitations of this approach are also clearly documented and listed in Component 3.

Caveats, limitations, data gaps, and a statement of confidence in the results are fully included in the report.

- The Index of Eutrophication builds upon the ASSETS tool developed by NOAA and is a quantitative assessment tool. Component 3 includes a section that specifically outlines ASSETS and compares it to the Index of Eutrophication developed for this project.
- Note that neither ASSETS nor the Index of Eutrophication developed by this project are truly predictive models, nor were they designed to be. They are assessment tools that can quantitatively characterize the condition of eutrophication. The QAPP does not mention predictive capacity as a desired aspect or goal of the Index of Eutrophication. The project and report cannot extend beyond the scope specified in the QAPP.
- The only year when no data were available for any indicator was 1992. No assessments are made for this year and no calculations of the Index of Eutrophication are presented for this year.
- The Key Findings note: "Increased availability of data would improve its resolution, though would not likely significantly change the conclusions of this report. Though monitoring intensified over time and the number of indicators monitoring are increasing, spatio-temporal alignment of data collection and increased sampling frequency will improve future assessments."

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"Report heavily weighted toward SAV; conclusions not in line with data: The report acknowledges that multiple years of condition data for various indicators of biotic condition are lacking. Only one year of benthic data were deemed useable. Clam data are limited. Even though data for SAV are not available prior to 2004 and widgeon grass data were first gathered during this study, the focus of the report is on the condition of SAV, with some discussion of clams. Declines in both SAV and clams are attributed to nutrient loading, in that nutrient loading affects light availability and algal community structure. It is stated that both resources have declined absolutely and also correlatively with an increase in nutrient loads. While absolute measures of SAV biomass and numbers of clams support that these two resources have experienced decline, the unconditional causation statement regarding nutrients is not well supported by data in the Bay and the literature."

- We are uncertain what the TAC refers to with regard to the statement "Report heavily weighted toward SAV". There are several seagrass indicators (5), but a similar number of indicators associated with water quality (4) and light availability (6). We have thoroughly documented the justification for including (or excluding) each indicator considered for this project.
- Seagrass data generated for this report was specified by the QAPP.
- Also as specified by the QAPP, the Index of Eutrophication is calculated for the time period 1989-2010, while seagrass data are only available 2004-2006, 2008-2010.
- In a holistic Index of Eutrophication assessment such as this, which draws upon modeling, data generation, and analysis of secondary data, it is critical to state upfront data availability and note where and when data gaps occur. This is noted in Table 3-2.
- We are unclear about the basis for the statement "conclusions not in line with data", nor what is meant by "declined absolutely". There is no instance of the phrase "declined absolutely" in the report or its revision. We provide descriptive statistics regarding each indicator observations, such as annual mean and standard deviation. In addition to the

raw and summary data provided, we include numerous figures and tables that provide evidence of the decline in various characteristics of seagrass (e.g. biomass) and clams (e.g. harvest) and the correlation between these biotic indicators and various other indicators observed and analyzed, as well as with nutrient loading.

- Contrary to the assertions by the TAC, the effects of nutrient loading on ecosystems and various biotic components (e.g. seagrass, macroalgae, phytoplankton, clams, etc.) is well established in the scientific literature in numerous ecosystems, coasts, and estuaries throughout New Jersey, the mid-Atlantic, and the world. Numerous examples, figures, and data have been included in this report to justify and document such statements. For the convenience of the TAC we have included pertinent figures from the literature in the report and have also made the full journal articles from which these figures and tables came from available to the TAC and other interested parties multiple times throughout the course of the project as documented in the quarterly progress reports.

Page 6 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"Literature supports that light availability is an important factor regulating seagrass growth and distribution. But light availability is affected by both factors that respond to nutrient enrichment (algae in the water column and epiphytic, macroalgal shading) and suspended solids, which consist of both biotic and abiotic components (algae, sand and other inorganic particles). Further, light availability is not the only important factor regulating SAV success. Factors besides light availability noted in the literature include: physical exposure, substratum, carbon, nutrients, temperature, salinity, oxygen, sulphide, competition and grazing. An obvious example of the importance of other factors is salinity, which limits the distribution of eelgrass in northern Barnegat Bay; in the northern Bay, widgeon grass is the dominant SAV species, as it prefers less salty water. These other factors should be explicit in the report."

- The Light Availability Index in this report consists of both biotic and abiotic factors affecting the ability of seagrass to photosynthesize regardless of their response to nutrient enrichment. As described in Component 3, the Light Availability Index includes chlorophyll *a* (commonly used as a standard proxy for phytoplankton abundance), the ratio of epiphyte biomass to seagrass biomass, macroalgae percent cover, total suspended solids (this includes sediment and other inorganic particles).
- The other factors noted in the report and literature (e.g. physical exposure, substratum, carbon, nutrients, temperature, salinity, oxygen, sulphide, competition and grazing) and their influence on the condition of seagrass are stated in Component 2.
- Note that temperature and dissolved oxygen are two factors considered in the Water Quality Index. No sulfide data have been collected in BB-LEH since 2001.
- Many of these other factors (physical exposure, substratum, carbon, sulphide, competition and grazing) are not mentioned in the QAPP and are outside the scope of work for this project. Data for many of these factors are not available in BB-LEH at either temporal or spatial scales necessary for an assessment of how these factors may contribute to the variability of seagrass conditions.

PAGE 7 (SECOND PARAGRAPH)

"Another problem with attributing SAV biomass decline solely to nutrients is that total nitrogen levels appear to be stable over the time period…Physical threats, such as use of watercraft in SAV areas, were not discussed at all…"

- Assessment and discussion of personal watercraft were not considered or discussed as they are outside the scope of this project and development of an Index of Eutrophication for the estuary. This project is limited to assessment of nutrient loading and eutrophication in support of nutrient management planning as specified by the QAPP.

- In regard to SAV biomass decline and nutrients, total nitrogen was not stable over the study period as advanced by the TAC comment. Actually, annual maximum concentrations of total nitrogen varied from < 500 μg L^{-1} to > 7,000 μg L^{-1}.

- The focus on nutrient concentrations in in water samples is a one-dimensional look at eutrophication of a coastal lagoon. It also yields an incomplete assessment of eutrophic enrichment and eutrophication of a coastal lagoon. Eutrophication in these enclosed waterbodies is closely coupled to the pool of nutrients contained in biotic (autotrophic) tissue and bottom sediments, and these media must also be assessed in eutrophication (McGlathery, 2001; McGlathery et al., 2007; Burkholder et al., 2007; Anderson et al., 2010). It is therefore important to examine nitrogen concentrations in biotic tissue (most notably benthic autotrophs) and in bottom sediments of the estuary concurrently with nitrogen concentrations measured in water samples. While the concentrations of nutrients in the water column may be stable between sampling periods, the amount in bottom sediments that recycle and fuel the growth of benthic microalgae and macroalgae may be quite variable. About half of the nutrients assimilated by seagrass, for example, are taken up from bottom sediments through the root and rhizome system and removed from pore waters. Hence, the amount of nitrogen in bottom sediments is certainly important. Bacterial decomposition of organic matter adds to the sediment pool. Nutrient release from bottom sediments to the water column can significantly accelerate system eutrophy, and this is why biotic responses in the benthos must be tracked. Eutrophy in a coastal lagoon is often not manifested by examining only chlorophyll *a* measurements, targeting phytoplankton, and tracking nutrient levels in the water column. In a coastal lagoon like Barnegat Bay-Little Egg Harbor, bottom sediments and benthic autotrophic dynamics likely play a more important role in the system eutrophy.

- Far greater concentrations of nitrogen are typically stored in bottom sediments of coastal lagoons (often 10-fold to 100-fold higher in bottom sediments than in the water column; Sand-Jensen and Borum, 1991; Burkholder et al., 2007). The bottom sediments serve as a large reservoir of nutrients (McGlathery et al., 2007; Anderson et al., 2010). Depending on the occurrence of benthic microalgae, sediment nitrogen (notably as ammonium) can be recycled to the water column under a wide array of conditions fueling algal blooms (Seitzinger et al., 2001). The occurrence of benthic microalgae clearly influences retention and transformation of nutrients in bottom sediments (Anderson et al., 2010). Internal nutrient loading via nutrient fluxes of stored compounds from sediments to the overlying water may thus be a far more significant process than loading from land at any one time in a coastal lagoon.

Key Citations

Sand-Jensen, K. and J. Borum, J., 1991. Interactions among phytoplankton, periphyton, and macrophytes in temperate freshwaters and estuaries. *Aquatic Botany*, 41: 137–175.

Page 7 of TAC Comments (on Interpretation of Results and Conclusions Drawn)

"The discussion on Biotic Response: Benthic Macroinvertebrates seems to indicate that several indices were considered but the REMAP index was used. The sources for other indices listed are not included as references. Please clarify what validation was done. See page 68 - "Validation of the methodology is conducted through comparison of multiple similar methods, and the response in 2011, as data from that year have been kept separate and out of analyses thus far."

- Since the other datasets were not used, they are not included in the references, nor are they included in the main body of the report. The analysis and validation of the conclusion regarding the other indices is included in the appendices. Including this information in the main body of the report is not considered appropriate because doing so could lead to confusion as to which datasets contributed to the results of the project. Nevertheless, including this information in the appendices is important in documenting the complete body of work conducted for this project and to fully demonstrate, document, and justify the approach, results, and conclusions of this project. As such, this appendix is an important part of this report.

Page 7 of TAC Comments (on Interpretation of Results and Conclusions Drawn)

"In addition to preferring more saline conditions, *Z. marina*, 1) prefers colder temperatures, with a range of -1° C in winter and 25° C in summer and 2) provided there is sufficient light for the species to succeed, at the lower end of the availability range, blade length increases and shoot density decreases, whereas with greater light availability, blade length decreases and shoot density increases. The study indicates the Barnegat Bay mean temperatures appear to be relatively steady, but monthly means as well as the maxima do exceed the 25° C threshold and appear to be trending upward in the north and central parts of the Bay. This suggests that temperature may be a significant stressor for eelgrass. An explanation is required for the selection of the temperature water quality threshold, which produces a favorable temperature index value, with an improving trend, contradicting this literature information. Further, with the exception of macroalgal shading, light availability factors appear to be favorable in the Bay, challenging the notion that light availability reductions are a significant cause of eelgrass biomass declines. The exception is the index value for macroalgal shading, but there are only a few data points for this factor. An explanation is needed for how the threshold was selected for the index. While overall biomass has declined, it is noteworthy that the *Z. marina* in the Bay exhibits shorter blade lengths and higher shoot density currently compared to the beginning of the study period, the same pattern as would be expected with a favorable light availability (assuming it is within the required range in the first place), according to the literature.

- Please cite specific sources when referring to the literature."
- We state "Optimal temperatures for growth and photosynthesis of seagrass (Lee et al. 2007) guided determination of temperature thresholds (Table 3-6)." Similarly, the thresholds for macroalgae percent cover are shown in Table 3-10.

- The TAC puts forth an interesting hypothesis regarding temperature as it relates to seagrass blade length and shoot density. Unfortunately, it is not in accord with the data and evidence presented in the report, has no statistical justification, and there is no evidence to suggest that temperature is or may be a significant stressor of eelgrass in BB-LEH.
- First, while there are observations of temperatures above the determined thresholds (see Table 3-8), annual mean temperatures <u>have</u> significantly changed over the study period (not "relatively steady") – but they change in the *opposite* direction of the TAC's assertion. Mean annual temperatures actually significantly ($p < 0.01$) decreased by 0.1°C in each segment. This is consistent with a favorable temperature index value and an improving trend, and with the literature indicating the suitability of cooler temperatures.
- Second, over the study period (1989-2010) blade length significantly ($p < 0.01$) decreased with temperature during June-July, did not change with temperatures during August-September, and significantly ($p < 0.01$) increased with temperatures during October-November. Moreover, over the study period (1989-2010) shoot density significantly ($p < 0.01$) increased with temperature during June-July, but did not significantly vary with temperature during either August-September, or October-November. These inconsistent seasonal relationships do not support the assertions made by the TAC.
- Third, Figure 3-32 does not support the assertion that "light availability factors appear to be favorable in the bay". This figure shows that indicators associated with light available have widely variable conditions over time, and that while some indicators exhibit sufficient light availability in some places some of the time these same indicators exhibit poor light availability in other places and/or at other times. For only a few examples, most light indicators (e.g. chlorophyll, epiphytes, total suspended solids) had poor condition in the central segment in 2005. Epiphyte condition received scores between 15 and 30 (out of 50) in the south segment from 1998-2003. Secchi depth never received a score greater than 40 (out of 50) in any segment in any year. Further, note that while light availability was greater than the minimum light requirements, it was generally less than optimal light requirements (Dennison et al. 1993, Orth et al. 2006).
- Fourth, the importance of macroalgal shading cannot be lightly waved away as an exception to the limitation of light available for eelgrass. Though there are few data points, macroalgae percent cover is consistent with a decrease in light available to eelgrass and increases in the frequency and intensity of macroalgae cover have been observed (Kennish et al. 2011, Fertig et al. 2012). Chi square analysis has shown that occurrences of macroalgae blooms at various levels of percent cover have significantly increased in frequency during 2008-2010 vs 2004-2006 (Fertig et al. 2012). We note: "Macroalgae 'Early Blooms' (70–80%) occurred twice during 2004–2006 and 17 times during 2008–2010 (chi square $p < 0.01$). Macroalgae 'Full Blooms' (>80%) occurred 12 times during 2004–2006 and 24 times during 2008–2010 (chi square $p < 0.05$)."
- Increased nitrogen in shallow water systems with adequate water clarity can lead to the replacement of eelgrass plants by opportunistic macroalgae (e.g. *Ulva* and *Enteromorpha*), filamentous epiphytic macroalgae, and benthic microalgae which require lower light intensities for survival, thus outcompeting and shading over the eelgrass, resulting in negative feedback (Hily et al., 2004; McGlathery et al., 2007). Macroalgae blooms (mainly *Ulva lactuca*) were commonly observed in Barnegat Bay-Little Egg Harbor (Kennish et al., 2011), increasing in frequency from 2004–2006 to 2008–2010

and thus diminishing light available to seagrass leaves. Blooms of sheet-like macroalgae can contribute to transfer of nutrients to sediments (Boyer and Fong, 2005). Resulting shifts in the composition of bottom-up controls also often resonates through upper trophic levels of an estuarine ecosystem. Additionally, light attenuation associated with epiphytes (10% of eelgrass biomass, Kennish et al., 2012), and detritus may be impacting *Z. marina* in Barnegat Bay-Little Egg Harbor Estuary. The loss of eelgrass habitat due to light attenuation affects trophic structure by reducing the abundance of herbivorous grazers that can control algal overgrowth (Burkholder et al., 2007). The resulting increase in algal epiphytes, therefore, may exacerbate eelgrass decline via reduced top-down control (Heck and Valentine, 2007).

Citations

Boyer, K.E., Fong, P., 2005. Macroalgal-mediated transfers of water column nitrogen to intertidal sediments and salt marsh plants. Journal of Experimental Marine Biology and Ecology 321, 59–69.

Burkholder, J.M., Tomasko, D.A., Touchette, B.W., 2007. Seagrasses and eutrophica- tion. Journal of Experimental Marine Biology and Ecology 350, 46–72.

Fertig, B., Kennish, M.J., Sakowicz, G.P. 2012. Changing eelgrass characteristics in a highly eutrophic temperate coastal lagoon. Aquatic Botany. DOI: http://dx.doi.org/10.1016/j.aquabot.2012.09.004

Hily, C., Connan, S., Raffin, C., Wyllie-Echeverria, S., 2004. In vitro experimental assessment of the grazing pressure of two gastropods on Zostera marina L. epi- phytic algae. Aquatic Botany 78, 183–195.

Heck Jr., K.L., Valentine, J.F., 2007. The primacy of top-down effects in shallow benthic ecosystems. Estuaries Coasts 30, 371–381.

Kennish, M.J., Fertig, B., 2012. Application and assessment of a nutrient pollution indicator using eelgrass (Zostera marina L.) in Barnegat Bay-Little Egg Harbor Estuary, New Jersey. Aquatic Botany 96, 23–30.

Kennish, M. J., B. M. Fertig, and G. P. Sakowicz. 2011. Benthic macroalgal blooms as an indicator of system eutrophy in the Barnegat Bay-Little Egg Harbor Estuary. Bulletin of the New Jersey Academy of Science, 57: 1-5.

McGlathery,K.J.,Sundbäck,K.,Anderson,I.C.,2007.Eutrophicationinshallowcoastal bays and lagoons: the role of plants in the coastal filter. Marine Ecology Progress Series 348, 1–18.

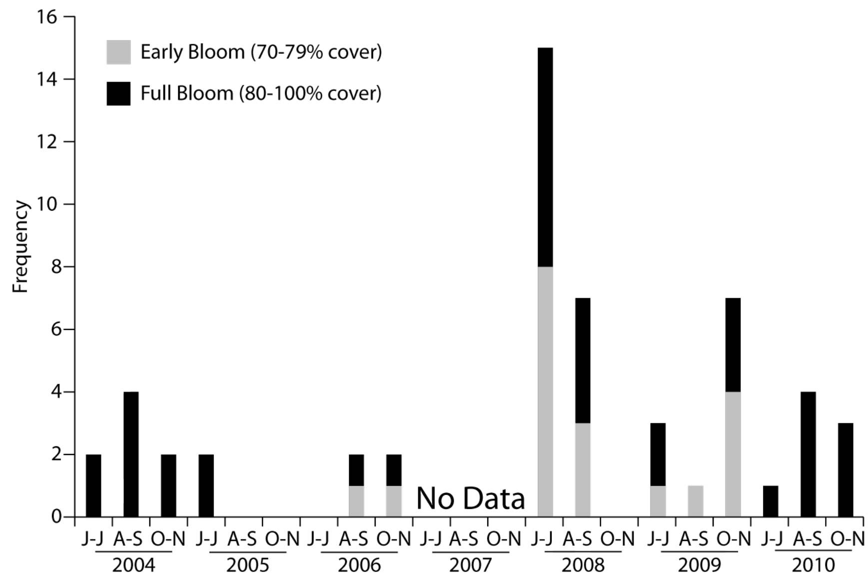

Figure 2- 10 Frequency of macroalgae cover at ‘Early Bloom’ = 70–79%, and ‘Full Bloom’ = > 80% conditions.

Page 7 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
“Suggests strong correlations and trends not supported by data and statistical tests; index conclusions unsound: In the description of several factors, a negative trend of biotic factors over time is suggested, but then a variable response is described year by year and an overall conclusion is reached that the “decline” tracks with nutrient increases. Yet the water quality factors remain relatively constant according to the data presented. Under these circumstances, it is difficult to accept a cause/effect relationship between the two. Examples: macroalgae coverage is higher in 2004, lower in 2006, higher in 2008 and lower in 2010, with the 2010 levels lower than the 2004 levels; eelgrass biomass has gone down-up-down-up as well, with the 2010 levels lower than the 2004 levels; water quality parameters have varied slightly but are not largely different at the end of the study period compared to the beginning—except that TP has increased. A number of correlation comparisons are offered in the report along with a conclusion that there is a correlation. However, not surprisingly, based on the above examples, the r or R2 value provided suggests little to no correlation. This uncertainty is not highlighted in the findings or the executive summary.”

- The statement “water quality factors remain relatively constant according to the data presented” does not accurately reflect the evidence presented in the report and is not backed up with statistical analysis. Figure 3-14 shows a significant ($p < 0.05$) relationship between total nitrogen loading from the watershed and total nitrogen concentration in the estuary. This is consistent with other findings in numerous estuaries worldwide and with the literature for Barnegat Bay (e.g. Kennish and Fertig 2012). Figure 3-16 shows significant ($p < 0.01$) inverse relationship between total nitrogen loading and various eelgrass characteristics (biomass, length, cover, shoot density). Figure 2-10 shows that occurrences of macroalgae blooms at various levels of percent cover have significantly increased in frequency during 2008-2010 vs. 2004-2006 (Fertig et al. 2012) and this is supported statistically through chi square analysis. Macroalgae ‘Early Blooms’ (70–80%) occurred twice during 2004–2006 and 17 times during 2008–2010 (chi square $p < 0.01$). Macroalgae ‘Full Blooms’ (>80%) occurred 12 times during 2004–2006 and 24 times during 2008–2010 (chi square $p < 0.05$). Year-over-year analysis or comparisons can be useful but is not always the best for examining complex ecological trends that are often non-linear and associated with multiple drivers. Rather, in such cases, the long-term trend identified through regression and time-series analysis is better at describing ecological change. Further, since multiple drivers interact in non-linear manners, it is reasonable for R^2 values of simple linear regression statistical models to be relatively low as these only consider a pair of variables at a time. In contrast, when integrating multiple indicators together – such as with the Index of Eutrophication, we can expect, and do indeed find, higher R^2 values, as shown in Figure 3-39, with significant trends over time ($p < 0.01$ in north and central segments, $p = 0.03$ in south segment) and reasonable R^2 values ($R^2 = 0.34$ in the north, $R^2 = 0.51$ in the central, and $R^2 = 0.21$ in the south).

Page 8 of TAC Comments (on Interpretation of Results and Conclusions Drawn)
"Even with the limitations already expressed with respect to developing the index, the researcher describes watershed pressure as moderate to good in Central and South, highly degraded in North; water quality as moderate or good in all three segments, except poor in 2010; light availability as moderate to excellent in North and South, but highly degraded Central; and seagrass response as highly degraded or poor in Central and South (eelgrass not present in North). So, using the index created in the report, it would seem difficult to conclude that water quality was the primary causal factor responsible for the condition of seagrass (data limitations here are that eelgrass data are absent prior to 2004 and widgeon grass was only quantified in this study; no earlier comparisons are possible). The overall index is given as moderate or better in Central and South, but poor in the North (where light availability is generally high, except for a dip in Secchi depth in 2008). With the inconsistencies between the biotic response and water quality, as well as the limitations noted (significant gaps in data), the findings must include caveats as to the uncertainties."

- As specified in the QAPP, the Index of Eutrophication is a quantitative tool. The descriptors are in place to help guide the interpretation of the numeric scores of the Index and its components. Note, however that each descriptor represents a fifth of the entire range of the Index of Eutrophication. Making conclusions by comparing the descriptors is therefore less accurate than by comparing the values of the Index of Eutrophication directly.
- Water quality, light availability, and other factors contribute to the condition of seagrass condition. As specified in the QAPP, the Index of Eutrophication is an assessment tool designed to identify the condition and trajectory of eutrophication in BB-LEH. It is not designed, and is beyond the scope of the QAPP to examine all factors contributing to biotic condition. Ultimately, nutrient loading influences both water quality and light availability. The report concludes that nutrient loading (not water quality, as written in the TAC comments, and which misconstrue the conclusions of the report) has led to eutrophication of BB-LEH. Further, the report specifies that the northern segment has already undergone a substantial amount of eutrophication though it has recently undergone modest improvements in condition. Meanwhile, though the central and southern segments are currently in better condition than the north, their trajectory is one of degradation as they are currently undergoing eutrophication.
- Caveats and limitations (which inevitably arise in projects that aggregate, integrate, and

analyze numerous datasets collected for a variety of purposes) are documented upfront and throughout the report.

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Second paragraph: "With only a few years of data it is hard to assess (and threshold values basis unknown), macroalgal coverage index is widely variable and very low in 2009. This would be a response indicator likely linked to nutrients and light availability, so warrants deeper investigation re: validity of the index threshold values as this could have a bearing on SAV, benthic organisms and DO. This data gap and its concomitant influences or uncertainties must be addressed."

- Threshold values for macroalgae percent cover are listed in Table 3-9. The basis for the determination of these thresholds is described in the section regarding threshold determinations.
- Macroalgae percent cover was not highly variable and during 1998-2010 was weighted 0.00 based on the eigenvectors that resulted from the PCA. Prior to 1998 there are no macroalgae percent cover data available and so this indicator is weighted 0.00 then as well. Therefore, macroalgae percent cover has very limited influence on the Index of Eutrophication values overall.
- We agree that additional research must be conducted on benthic macroalgal blooms in BB-LEH. Previous research has observed a significant increase in the frequency and intensity of these blooms (Kennish et al. 2011), and that these blooms are likely having an impact on seagrasses and contributing to their decline (Fertig et al. 2012).

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Third paragraph: "Quarterly progress report for the period January 1, 2012 through March 31, 2012 included graphs showing data collected for water quality. Total Nitrogen was less than 800 ug/l for all years in all three segments. When the total nitrogen scores were presented on a scale of 0 to 100, the scores for the central and the south segments were generally 80 to 100 or "excellent". The north section dipped to about 70 or "good". While there appears to be a little more variability in the north section, the south and central are relatively stable. This does not support the key finding – "the condition of the BB-LEH has progressively worsened over time for both nitrogen and phosphorus. The basis for the statement must be explicit."

- Quarterly progress reports showed water quality data that were available and showed preliminary thresholds and preliminary results at the request of the TAC. The status of these thresholds and scores as preliminary was stated in writing and communicated through oral presentations. The final report that was submitted includes additional analysis that was conducted between the dates mentioned and the submission of the final report.
- The basis for the statement quoted is Figure 3-31, Figure 3-36, and Figure 3-39. These figures are now cited to support the statement quoted.

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Third paragraph: "Estuarine segmentation – in many places the report indicates that the north, central, and south sections of BB-LEH behave differently. However, metrics, thresholds, data and conclusions do not appear to be based on segmenting the bay."

- Estuarine segmentation is based on statistically significant differences in the characterization, behavior, and response of the regions with respect to a variety of physical, geological, chemical, water quality, and other variables, as has been demonstrated and documented.
- Establishing different metrics and thresholds for different segments of BB-LEH would distort or bias comparisons of these different segments such that the Index of Eutrophication could not be compared between regions and could not be averaged among all regions in order to compute an average value for the entire BB-LEH.
- All data have been analyzed according to the segment in which it was collected. These are clearly shown in each figure and table unless a bay-wide average (or other measure of central tendency) has been calculated.
- Conclusions have been made regarding each segment of the bay. Generalizations for the whole BB-LEH complex are made by averaging results from all three segments.

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"It appears that several of the conclusions drawn are not supported based on the historical data provided in the Ecology of Barnegat Bay New Jersey, Kennish M.J. and R.A. Lutz 1984."

Macroalgae: "Recurring macro algae blooms *Ulva lactuca, Gracilaria tikvahiae, and Enteromorpha intestinalis*, are listed as a cause impacting the growth of eelgrass. See page 87. From 1969 to 1973 *Ulva lactuca* was the most dominant macrophyte species present in the Barnegat Bay with some of the others listed being in the top ten. Is the current condition worse than what was documented in the late 60's and early 70's?"

- The book edited by Kennish and Lutz (1984) does not provide quantification of macroalgal bloom events in the estuary over the 1969 to 1973 period. Can the TAC provide a times series of macroalgal blooms and count of macroalgal bloom events that occurred in the estuary during the late 1960's to early 1970's, notably in seagrass beds during that stretch of time? Those data are not available. Secondly, those data would be of no significance to the development of an Index of Eutrophication in this project anyway, which targets the 1989 to 2011 time frame – as specified by the QAPP.

- While it is interesting attempting to hindcast to 1960's databases that may exist for comparison, these old databases are not sufficient to determine trends of past macroalgal bloom condition in seagrass beds over a great expanse of the system. Data on macroalgal bloom events in seagrass beds are needed in our approach to develop an accurate Index of Eutrophication, but within the specified period of study noted in the QAPP from 1989 to 2011. While we do not know the systematic state or quantification of macroalgal blooms during the 1960's in seagrass beds of the system based on the work of Taylor or others, what we do know at the current time is that the estuary experiences frequent and significant macroalgal blooms in many different areas of the estuary. In addition, we also know that Barnegat Bay-Little Egg Harbor is a eutrophic estuary as determined by the studies of Seitzinger et al. (2001), Bricker et al., (1999, 2007), Kennish et al. (2007, 2008, 2010), and Fertig et al. (in press). Certainly, this has been corroborated by different investigators working over a 20-year period of time. This is where the focus should be to address the remediation that is necessary to restore the integrity of the estuary – not on possible bloom events four decades ago.

- Jonathan Taylor's work in Barnegat Bay (Taylor, J. E. 1970. The ecology and seasonal periodicity of benthic marine algae from Barnegat Bay, New Jersey. Ph.D. Thesis, Rutgers University, New Brunswick, NJ.) was a component of a broad abiotic/biotic study conducted by Rutgers University under the direction of Dr. Robert E. Loveland to assess estuarine conditions in the central area of Barnegat Bay prior to operation of the Oyster Creek Nuclear Generating Station (OCNGS). The goals/objectives of that study were different than the studies conducted by Rutgers over the 2004-2011 period. The earlier studies were conducted to establish a baseline of data before operation of the OCNGS that could be compared with conditions in the estuary after it began operation in December 1969. A series of technical reports was completed by Dr. Loveland's students and support staff (including Jonathan Taylor). These reports were submitted to the NJDEP on a regular basis, and therefore they should be available at the NJDEP..

- Taylor did not conduct his study estuary-wide and did not conduct his study to specifically assess macroalgal blooms in seagrass beds. It did not cover the seagrass beds on the east side of the estuary along the entire central and south segments of the estuary. Therefore, his study was not spatially or temporally comparable to the current study conducted by Rutgers during the 2004 to 2011 period, and it did not address the same questions. In addition, the approaches and methods of the two studies differed substantially; Taylor did not use the SeagrassNet approach to examine seagrass and macroalgae characteristics. Therefore, results of the Taylor project during the 1960's cannot be accurately compared with those of the current project conducted from 2004 to 2011.

- Furthermore, macroalgal dominance (as reported in Table 4 of Kennish and Lutz, 1984) does not translate into macroalgal bloom occurrence or documentation. Table 4 derived from Taylor's work in the 1960's is a listing of the dominant macroalgal species in the estuary for his study period. It is not a listing of annual macroalgal bloom occurrence, frequency of occurrence, or location for that period, nor does it show temporal trends of bloom occurrence comparable to that done for the 2004-2011 period and documented in the NEIWPCC report. In fact, macroalgal bloom occurrence for the 1960's is not reported at all in Kennish and Lutz, 1984. Taylor's research on benthic algae in the Barnegat Bay-Little Egg Harbor during the 1960's did not target bloom occurrence of macroalgae in any systematic way within seagrass beds, and his work was not driven by a hypothesis focusing on eutrophication of the system and data collected to assess that hypothesis (but rather it was linked to operation of the OCNGS), including the detailed observations at 120 sampling stations along 12 transects of seagrass beds in the estuary that were conducted by Rutgers and included in the NEIWPCC report. So, it is not possible to make accurate comparisons of the two studies.

- There is no universal – or even commonly used – definition of a macroalgal bloom. In addition, there are really few standard methods for even measuring macroalgal abundance. Two of the accepted standard methods in the scientific community are macroalgal areal cover and biomass (Peggy Fong, University of California Los Angeles, personal communication).

- While macroalgal blooms may have occurred in the estuary during the 1960's, this is true of most shallow estuaries and coastal lagoons (Valiela et al., 1997). However, this does not tell us anything about the frequency, magnitude, and extent of bloom events for that period and their impact on seagrass beds, nor does it tell us anything about eutrophic condition or eutrophic link. We targeted macroalgal blooms in seagrass beds for our project because that is an important element/indicator used in development of the Index of Eutrophication for the estuary over the 1989-2011 study period. Taylor (1970) did not do that. In fact, macroalgal bloom activity may be much worse over the past decade than four or five decades ago; evidence from the Seawood Harbor macroalgal bloom event alone in 2011 indicates that such recent bloom events have become very serious in the system. The link between macroalgal bloom occurrence and decline of seagrass in nutrient-enriched coastal waters is well established in the scientific literature (McGlathery, 2001; Burkholder et al., 2007; McGlathery et al., 2007)

- The magnitude, frequency, and extent of macroalgal blooms must be measured annually over a protracted period to determine if they are increasing, decreasing, or remaining unchanged through time (Lyons et al., 2012). Our method of using percent macroalgal areal cover of the seagrass bed provides an accurate systematic and quantitative approach to assess macroalgal blooms in the estuary, most notably in seagrass habitat. This approach indicates that the bloom events have increased over the 2004-2010 period of study (Kennish et al., 2011).

- Certainly, Paul Bologna (2000) reported heavy macroalgal blooms in the late 1990's, but this was well within the time period of increasing eutrophic condition of the estuary reported by Seitzinger and Bricker, when Bologna also reported a dramatic decline in seagrass areal cover. What we have stated, and what we have backed up with data in the NEIWPCC report, is that there has been a significant number of macroalgal blooms occurring in the seagrass beds of the estuary during the 2004-2010 period, and that bloom occurrence has increased over this period. In addition, the blooms have been detrimental to seagrass habitat in the system. Looking for macroalgal blooms in the 1960's -- whose magnitude, frequency, or areal cover have not been determined for seagrass beds across the system -- does not diminish our recent findings. Similar findings of macroalgal bloom impacts on seagrass have been reported for other eutrophic coastal bays (McGlathery, 2001 Burkholder et al., 2007; McGlathery et al., 2007; Anderson et al., 2010). In fact, macroalgal blooms are a most common occurrence in eutrophied lagoonal systems.

- As a final note Valiela et al. (1997, page 1105) made the following statement 15 years ago: "The appearance of dense canopies of macroalgae in benthic communities of shallow water bodies is an increasingly common phenomenon along virtually all of the world's shorelines. Even a short list of published studies attests to the widespread distribution of macroalgal blooms." Such blooms have been linked to increasing nutrient enrichment and eutrophication of these waterbodies (McGlathery, 2001 Burkholder et al., 2007; McGlathery et al., 2007; Anderson et al., 2010).

- **Key Citations**
  Fertig, B. M., G. P. Sakowicz, M. J. Kennish. 2012. Changing eelgrass (*Zostera marina* L.) characteristics in a highly eutrophic temperate coastal lagoon. *Aquatic Botany.* (In press).

- Lyons et al. 2012. What are the effects of macroalgal blooms on the structure and function of marine ecosystems? A systematic review protocol. *Environmental Evidence* 2012: 1-7.

- McGlathery, K. J. 2001. Macroalgal blooms contribute to the decline of seagrass in nutrient-enriched coastal waters. *Journal of Phycology* 37: 453-456.

- Valiela, I., J. McClelland, J. Hauxwell, P. J. Behr, D. Hersh, and K. Forman. 1997. Macroalgal blooms in shallow estuaries: Controls and eophysiological and ecosystem consequences. *Limnology and Oceanography* 42: 1105-1118.

Phytoplankton: "A portion of the NEIWPCC Report talks about the change of the phytoplankton to smaller species or picoplankton, which negatively impact the clam growth and is a sign of ecosystem change. What is not discussed is the large abundance of small plankton species present during the summer months (June thru Sept) that were called ultraplankton, very small plankton species, present in the Bay up to 800,000 cells/ml, during the late 60's and early 70's by Kent Mountford. See page 64. The presence of picoplankton is not new in Barnegat Bay."

- While it is interesting attempting to hindcast to 1960's phytoplankton databases that may exist for comparison, these old databases are not sufficient to determine trends of past phytoplankton characteristics over a great expanse of time and space for the system. Furthermore, these data from more than four decades ago have no significance to the development of an Index of Eutrophication for this project which targets the 1989 to 2011 time period – as specified in the QAPP.

- Kent Mountford did document ultra- and nanoplankton in the estuary in the 1960's. However, what the comment above fails to mention is the occurrence of brown tide (*Aureococcus anophagefferens*), which has a dramatic impact on shellfish growth and mortality (Cosper et al., 1987; Tracey, 1988; Bricelj et al., 2001; Popels et al., 2003). Brown tide blooms were not reported in the estuary during the 1960's, 1970's, or 1980's. Similar to other impacted coastal bays in Maryland and elsewhere (Bricelj and MacQuarrie, 2007; Bricelj, 2009; Glibert et al., 2001; Glibert et al., 2010), significant brown tide blooms were reported over the 1995 to 2002 period in Barnegat Bay-Little Egg Harbor indicating a serious change in picoplankton composition and abundance during the increasing eutrophic period of the estuary (Gastrich et al., 2004). Brown tide blooms of 1-2 million cells/ml were recorded in the estuary during the 1998-2002 period. Brown tide blooms were not reported by Kent Mountford, and they certainly account for a different level of impact on shellfish populations (Bricelj and MacQuarrie, 2007).

Chlorophyll a: **"**Chlorophyll *a* range in Barnegat Bay is generally 1-12 µg/l, with a maximum concentration in excess of 40 µg/l between 1989 and 2010. Samples collected in the central portion of Barnegat Bay in a 22 month period from 1969 to 1970 show generally the same general concentration of 1-12 ug/l with a maximum of 35 µg/l. See chart on page 69. It would appear that chlorophyll *a* levels have not changed much over the past forty years."

- It is important to note that phytoplankton primary productivity and chlorophyll *a* may be consistent through time in coastal lagoons, while in deeper estuarine ecosystems these parameters typically increase as a linear function of nitrogen loading. In coastal lagoons autotrophic production may accelerate in the benthos, where light penetrates to the bottom. The linear increase of phytoplankton productivity with an increase in nitrogen loading seen in the deeper ecosystems is a key response anticipated by environmental managers. In coastal lagoons, however, tipping points pursued by environmental managers are often not observed. As noted by Robert W. Howarth (Cornell University, personal communication), "managers tend to assume a linear increase in productivity and eutrophication with increased nitrogen loading, as in deeper plankton-based systems, even though production stays level over a wide range of increasing load, until seagrasses die-off and the system enters a totally new state." Nixon et al. (2001) showed that in shallow coastal systems (<2 m), there was no clear correspondence between N inputs and primary production, whereas in deeper estuaries (>5 m) water column chlorophyll and phytoplankton primary production were correlated with N loading. The work of Borum and Sand-Jensen (1996) supports this finding. This is why managing coastal lagoonal systems is particularly problematic, and intervention may be delayed until eutrophication impacts significantly worsen. We have to turn attention in particular to the benthic flora when tracking responses to nutrient enrichment and eutrophication in coastal lagoons, where overt changes often are manifested.

- We do not have chlorophyll *a* measurements at regular intervals estuary-wide between the 1960's and 2011 so that an accurate trend of data cannot be developed. The TAC comment here provides no trend at all. While it is interesting attempting to hindcast to 1960's chlorophyll *a* databases that may exist for comparison, these older chlorophyll databases are not sufficient to determine long-term trends over the expanse of the estuary. In addition, chlorophyll *a* values from 40 years ago are outside the timeframe targeted by this study to develop an Index of Eutrophication (over the 1989-2011 period) as specified in the QAPP.

- Furthermore, the TAC comments presented above completely avoid the occurrence, enumeration, and effects of brown tide, which would not be evident from Mountford's phytoplankton work of the 1960's, since brown tide did not occur in the estuary until much later. It is also important to note here that chlorophyll *a* is not an effective way to monitor or measure for brown tide anyway because *Aureococcus anophagefferens* does not leave a chlorophyll *a* signature. Occurrence of brown tide blooms would not translate into elevated or spike measurements of chlorophyll *a* in the estuary, yet their presence could be significantly detrimental to shellfish populations and seagrass habitat, playing a potentially important role in the loss of both. This is directly relevant to the lack of brown tide monitoring and data in the estuary since 2004.

- Because *Aureococcus anophagefferens* does not leave a clear chlorophyll *a* signal, blooms typically go unnoticed and unchecked without a comprehensive and consistent monitoring program for HABs. Without such a program, there will likely be underestimates of HAB events and their impacts in the estuary. So, while chlorophyll *a* levels may appear to have remained unchanged, the composition of the phytoplankton community certainly has shifted with the occurrence of brown tide blooms alone as reported by the NJDEP; the occurrence of brown tide blooms have taken place during the period of increasing eutrophic condition in the estuary in the 1990's and after 2000 (Seitzinger et al., 2001; Bricker, 1999, 2007; Kennish et al., 2007).

- As noted by Popels et al. (2003) and others, such HABs appear to be increasing in frequency around the world linked to nutrient enrichment, and most are undetected. As reported by Anderson et al. (1993) and many others, identification of brown tide with standard light microscopy is "uncertain," and therefore an inaccurate and unreliable way to identify and (certainly) one incapable of accurately quantifying brown tides. Two effective and accurate ways to detect and enumerate brown tide are the application of monoclonal-antibody techniques (Caron et al., 2003) or use of quantitative polymerase chain reaction (Popels et al., 2003), which enable the detection of cells at even extremely low concentrations.

- The TAC comment on page 18 for Harmful Algal Blooms (top of page) notes that the DEP used remote sensing with follow-up monitoring and species identification after 2004 to check for brown tide. Species identification? See comments above. What approach was used for species identification? The use of standard light microscopy in the laboratory to identify and enumerate brown tide is a seriously flawed approach as documented by Anderson et al. (1993). The questions are these: What methods were used to identify and enumerate brown tide during each bloom event after 2004? Which years were monitored and how many stations in the estuary were sampled? Was the sampling statistically valid? If routine monitoring for brown tide was not conducted in the field after 2004, bloom events certainly could be missed because brown tide does not leave a chlorophyll *a* spike or signal in remote sensing applications. How were the samples enumerated? If they were enumerated, the archived data must now be available for additional index calculations and should be provided to us.

- **See Following Papers:**
- Nixon, S, B., B. Buckley, S. Granger, and J. Bintz. 2001. Responses of very shallow marine ecosystems to nutrient enrichment. *Human Ecological Risk Assessment* 7: 1457-1481.

- Caron, D. A., R. Dennett, D. M. Moran, R. A. Schaffner, D. J. Lonsdale, C. J. Gobler, R. Nuzzi, and T. I. McLean. 2003. Development and application of a monoclonal-antibody technique for counting Aureococcus anophagefferens, an alga causing recurrent brown tides in the mid-Atlantic United States. *Applied and Environmental Microbiology* 69: 5492-5502.

- Popels, L. C., S. C. Cary, D. A. Hutchins, R. Forbes, F. Pustizzi, C. J. Gobler, and K. J. Coyne. 2003. The use of quantitative polymerase chain reaction for the detection and enumeration of the harmful alga *Aureococcus anophagefferens* in environmental samples along the United States East Coast. *Limnology and Oceanography: Methods* 1: 92-102.

Hard Clams (*mercenaria mercenaria*): "The Division of Fish and Wildlife studies have documented a population decline and poor recruitment in Hard Clams in the Little Egg Harbor. However, the hard clam population in the central portion of Barnegat Bay was determined to be less than 0.1 clams/ sq. meter in the 1960's. See page 178-180. It appears that the historical levels were less than 0.7 clams/ sq. meter, the minimum density suggested to be necessary to sustain a viable population."

- There is no mention in the TAC comments above to the work of Vouglitois and Kennish (1980) who conducted population surveys on hard clams in central Barnegat Bay during 1978 and 1979. Results of the Vouglitois and Kennish surveys are summarized on pages 181 and 182 of the book edited by Kennish and Lutz in 1984 (*Ecology of Barnegat Bay, New Jersey*). It is necessary to revisit the discussion of these surveys as documented in the Kennish and Lutz volume. In brief, Vouglitois and Kennish surveyed the density and distribution of hard clams in central Barnegat Bay during 1978 and 1979 in the same general area of the bay surveyed by Campbell (1969), which is discussed below. They found eight areas in the central bay where hard clam densities were 1.5-2 clams/sq m (see Figure 3, page 182 in Kennish and Lutz, 1984). In addition, they found densities of recently-set clams between 1 and 5 mm in length ranging from 20 to 1580 sq m in 1978 and from 4 to 80 sq m in 1979. The occurrence of young-of-the-year clams coincided, to a large degree, with that of adults, indicating a healthy reproducing population. Vouglitois and Kennish also reported an increase in clam densities toward the southern margin of the survey area, similar to the finding of Campbell (1969). Clams greater than 66 mm in length comprised 70.5% of the population in the survey area during 1978. These findings do not support the TAC comments.

- Campbell (1965, 1966, and 1969) conducted surveys of the hard clam population in a limited part of the center of the bay (where Vouglitois and Kennish later conducted hard clam surveys) to establish a baseline database for future assessment of possible impacts of operation of the OCNGS. Campbell's surveys were not conducted along the east side of the bay; they extended from about Stouts Creek to Lochiel Creek. Areas south of Lochiel Creek near Gulf Point, which were historically good recreational/commercial shellfishing areas, were not sampled. Campbell noted that densities of hard clams increased toward the bay's southern perimeter, but sampling was not conducted south of Lochiel Creek.

- During the past 50 years, only one baywide survey of the hard clam stock was conducted in Barnegat Bay (in 1986). A 1963 survey was conducted by the US Department of Interior using an interview-based survey with distribution charts derived from the interviews, certainly not the most accurate approach for shellfish assessment. Joseph conducted an inventory of Barnegat Bay shellfish resources in 1986, the most complete stock assessment after 1963. A second survey of hard clams is being conducted now in Barnegat Bay. That means a hiatus of more than 25 years between the hard clam survey in 1986 and that in 2012 in Barnegat Bay. Until that data is available, there is no way we can accurately determine the change in stock level of hard clams in Barnegat Bay over the past 25 years. Anecdotal evidence, however, strongly suggests that the hard clam stock in Barnegat Bay, like that in Little Egg Harbor, has dramatically declined over the past 25 years. Results of the 2012 hard clam survey in Barnegat Bay will provide quantitative data necessary to determine the present stock condition.

- In regard Little Egg Harbor, the hard clam population was certainly present at levels well above 0.7 clams/sq m (and above the level necessary for viable reproduction) during the shellfish survey conducted by the DEP in 1987, yet the population essentially crashed after that time. The report by Celestino (2003) clearly shows the severity of the population decline. The hard clam population in Little Egg Harbor also was exposed to the brunt of the brown tide blooms occurring in the estuary during the 1995-2002 period, which falls within the period of rapid decline of hard clam abundance. That needs to be considered as well.

Nutrients: "Nutrients (Total Nitrogen and Total Organic Nitrogen) in the Manahawkin Bay to Little Egg Harbor area seemed to have decreased from the 1970's to the current 2011-2012 data, even though these areas have seen some of the largest percentage change in population growth over the last 40 years. Stafford Township, 720% increase, Little Egg Harbor, 675%. Stafford grew from about 4,000 in 1970 to approximately 27,000 in 2010. Little Egg Harbor grew from 2,972 in 1970 to 20,065 in 2010. Data from research performed by Durand from Manahawkin Bay to Little Egg Harbor, in the book by Kennish M.J. and R.A. Lutz 1984, *Ecology of Barnegat Bay, New Jersey*, and comparing it to data collected during the Barnegat Bay Sampling from the summer of 2011 to the summer of 2012. In spite of the population increase over the last 40 years, Total Nitrogen (TN) and Total Organic Nitrogen (TON) concentrations in Manahawkin Bay have declined from an average of 510 µg/l TN and 489 µg/l TON, while the 2011-2012 data shows 340 µg/l TN and 291 µg/l TON. Reviewers would be interested in knowing the author's reasoning for the divergence of his historical data and current conclusions."

- While it is interesting hindcasting nutrient data to 1970's databases that may exist for comparison, these old databases on nutrients are not sufficient to determine trends over the past 40 years and over the expanse of the estuary. What data are provided for the years between the 1970's and 2011-2012 for comparison and trends?

- In addition, nutrient levels from 40 years ago are outside the timeframe targeted by Rutgers to develop an Index of Eutrophication (over the 1989-2011 period) as specified in the QAPP.

- Levels of 340 µg/l TN and 291 µg/l TON in Manahawkin Bay do not mean they are below a tipping point for eutrophication of these waters. In fact, these nitrogen levels may be well above the tipping point for waters having restricted circulation. Manahawkin Bay appears to have a protracted water residence time; this means nutrients in the water column even at seemingly lower levels can concentrate through time in biotic tissue and, even more so, in bottom sediments where they serve as a significant secondary source for release to the sediment water interface and water column at later periods of time to stimulate autotrophic growth. Without knowing the nutrient levels existing in biotic tissue as well as in bottom sediments in the 1970's makes any comparison with conditions 40 years later highly tenuous at best.

- Variable levels of nitrogen in the water column do not mean the accumulation of nitrogen in bottom sediments and benthic vegetation is not elevated. In addition, it is important to know the sampling locations, number of sampling stations, frequency of sampling, and conditions at the time of sampling in the 1970's relative to sampling in 2011-2012. How many stations have been sampled, and are the number and frequency of sampling events statistically valid for both databases for accurate comparison? Especially noteworthy is the following: What are the measures of the nitrogen concentrations in biotic tissue and bottom sediments that are necessary to accurately assess condition?

- Secondly, dissolved organic nitrogen is the far more abundant form of nitrogen (about 10 times more abundant than dissolved inorganic nitrogen) in the south segment of Barnegat Bay-Little Egg Harbor system (than in the central and north segments), comprising most of the TON there (Seitzinger et al., 2001). This contrasts with the predominant inorganic nitrogen forms in the north segment of the estuary. A large component of the dissolved organic nitrogen likely derives from adjoining salt marsh habitat bordering Manahawkin Bay and Little Egg Harbor. The concentrations of TON in Manahawkin Bay, therefore, may have little to do with population growth and development in Stafford Township.

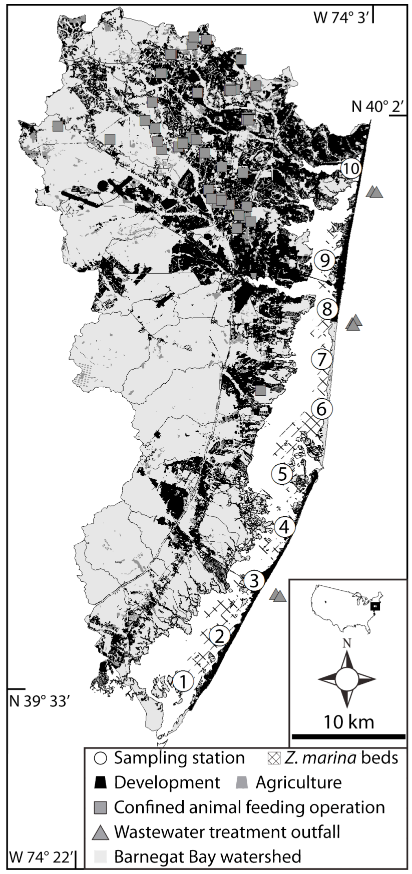
- Another element must be considered. What data have been included in the nutrient measurements and what data have been left out for accurate assessment? Measurements of nitrogen concentrations in bottom sediments should also be measured and included since the sediments serve as a larger secondary pool of nitrogen than what is found in the water column; far larger concentrations of nitrogen are stored in bottom sediments of coastal lagoons, and they can be released to the water column at variable times due to natural and anthropogenic factors (Sand-Jensen and Borum, 1991; McGlathery et al., 2007; Burkholder et al., 2007; Anderson et al., 2010). Nitrogen released from bottom sediments to the water column, therefore, should be measured frequently – as well as those in the water column – since there is high variability in the dynamics of nutrient exchange. This means that if nutrient sampling is conducted once every three months or even a few times a month in a coastal lagoon, the variability may be too great for statistical accuracy.

- Remineralization is an important internal source of nitrogen to coastal lagoons. Benthic microorganisms play a critical role in the regulation of benthic-pelagic nutrient exchanges in these water bodies. Depending on the occurrence of benthic microalgae, sediment nitrogen can be recycled to the water column from sediment pore waters under a wide range of conditions (Seitzinger et al., 2001). Internal nutrient loading via nutrient fluxes of stored compounds from sediments to the overlying water may be a far more important process than loading from land at any one time, even though most of the original load of nutrients originated from coastal watershed areas. These conditions may vary considerably from week to week, month to month, and certainly from year to year depending on storm occurrence, winds, and abundance and type of benthic organisms that roil bottom sediments via bioturbation. Therefore, in a coastal lagoon it is important to frequently measure nitrogen concentrations in all three media in a given year (water column, autotrophs, and bottom sediments) to effectively assess source and concentrations of both TN or TON in the water column. Nitrogen dynamics must be understood in the three major media to delineate why Manahawkin Bay may be eutrophic.

- Because of the shallow depths of Barnegat Bay-Little Egg Harbor, there is a tight benthic-pelagic coupling (Seitzinger et al., 2001), as has been demonstrated in other coastal lagoons (McGlathery, 2001; Burkholder et al., 2007; Anderson et al., 2010). In these systems, water quality monitoring of nitrogen concentrations provides only a part of the database necessary to completely assess ecosystem condition – or source of the nitrogen. It also does not reflect biogeochemical processing in bottom sediments, how much nitrogen is sequestered in the sediments that may vary from year to year (and may be released to the water column), and the role of benthic microalgae in removing nitrogen released from the sediments before it reenters the pelagic domain as examined by Seitzinger et al. (2001). These processes, again, affect nitrogen levels in the water column. Therefore, high or low nutrient concentrations in the water column taken 40 years ago, without any measure of biomass of benthic autotrophs or bloom occurrence, and bottom sediment nutrient levels, tells us little, if anything, about overall nutrient dynamics of the system.

- Touchette and Burkholder (2000) reported that phosphate in the water column of seagrass habitats typically range from ~0.1 to 1.7 µM compared to higher concentrations in sediment pore water ~0.3 to 20 µM. Ammonium levels in the water column were reported at 0 to 3.2 µM in the water column compared with ~1 to 180 µM in sediment pore water. Finally, nitrate + nitrite concentrations were reported at ~0.05 to 8 µM in the water column compared with ~2 to 10 µM sediment pore water.

- The amount of nitrogen in plant tissue cannot be discounted either. For example, in a study by Kennish and Fertig (2012) referenced directly below, nitrogen concentrations were measured in *Zostera marina* leaves along a transect of 10 sampling stations in all three segments of the estuary. Mean leaf nitrogen concentrations ranged from 1.05 to 3.94%, reflecting a considerable amount of nitrogen assimilated from the water column and sediment pools and sequestered in plant tissue. This is a substantial amount of nitrogen when considering all seagrass leaves in the estuary. In addition, it does not consider the large amount of nitrogen concurrently bound up in the tissues of macroalgae and microalgae along the estuarine floor, which would be assimilated even faster than that taken up by seagrass.



- Kennish, M. J. and B. Fertig. 2012. Application and assessment of a nutrient pollution indicator using eelgrass (*Zostera marina* L.) in Barnegat Bay–Little Egg Harbor estuary, New Jersey. *Aquatic Botany* 96: 23-30.

- Moreover, low levels of TN or TON in water samples during spring and summer months may also correlate with concurrent periods of high macroalgae biomass and high abundance of benthic microalgae – even frequent and extensive ephemeral blooms -- that can rapidly sequester nitrogen, thereby reducing water column levels. However,, high levels of TN or TON in the water column may contrast with low levels of nitrogen in benthic vegetation. Nitrogen concentrations can vary considerably in these media from year to year. BB-LEH is a dynamic system requiring more than just nutrient measurements in the water column measurements, which often do not reflect eutrophic conditions in coastal lagoons such as BB-LEH.

- This is a major reason why this project was undertaken to develop an Index of Eutrophication for BB-LEH. It has been recognized for years that multiple water quality and biotic indicators must be measured in a coastal lagoon like BB-LEH to achieve accuracy of ecosystem assessment for eutrophication. It is necessary to examine water column, biotic, and sediment parameters to accurately assess ecosystem condition. It is clear that there are significant weaknesses of using only one indicator to determine ecosystem impairment or condition.

See Following Papers:

- Kennish, M. J. and B. Fertig. 2012. Application and assessment of a nutrient pollution indicator using eelgrass (*Zostera marina* L.) in Barnegat Bay–Little Egg Harbor estuary, New Jersey. *Aquatic Botany* 96: 23-30.

- Touchette, B. W. and J. M. Burkholder. 2000. Review of nitrogen and phosphorus metabolism in seagrasses. *Journal of Experimental Marine Biology and Ecology* 250: 133-167.

RESPONSE TO PAGE-SPECIFIC COMMENTS

PAGE 9 (OF TAC COMMENTS TO ACKNOWLEDGEMENTS)

"The acknowledgements section should include all members of the technical advisory committee. Debra Hammond, Stan Hales, and Jim Vasslides have been left off the list."

- These names are now included as well.

PAGE 9 OF TAC COMMENTS TO KEY FINDINGS

"Includes an extensive use of acronyms that make this portion of the document difficult to read. It may be helpful to provide the full terms and information that highlights the significance of the findings for the general audience in this section."

- Acronyms have been spelled out with the exception of BB-LEH for Barnegat Bay-Little Egg Harbor, and this acronym is spelled out with its first usage. While not ideal to include BB-LEH as an acronym at all in the Key Findings section, it is necessary to keep this section as short as possible.

PAGE 9 OF TAC COMMENTS TO KEY FINDINGS

"Having a key findings section is a good idea, but the section needs to be simplified. As is, this section is not reader friendly for a general audience."

- This section has been simplified. Acronyms have been spelled out. Information has been grouped according to theme and main message. Extraneous data and facts garnered from the literature have been removed. We include succinct information from the watershed and nutrient loading components of this project.

PAGE 9 OF TAC COMMENTS (TO PAGE 13 OF THE REPORT)

"First bullet - This is not a finding but a statement of condition. Loads need context (how high is this comparably) and the detailed USGS modeling info on both nitrogen and phosphorus, as well as the differences in spatial loadings from north to south."

- The statement of condition and quantification of load is a Key Finding and Result of this project. Statement of the loading and condition of BB-LEH meets the stated objectives of this project as specified in the QAPP. Context of loads is provided later, in comparison to the Index of Eutrophication. Detailed USGS modeling information on both nitrogen and phosphorus is included. This information includes differences in spatial loadings from north to south.

PAGE 9 OF TAC COMMENTS (TO PAGE 13 OF THE REPORT)
"Second bullet - No context is provided. There are no indications of how frequent or what percentage of the measurements were exceedances for many variables and any trends analysis performed. An increasing or decreasing trend would be a key finding. The above statement also implies that all of the above referenced factors directly led to degradation of sea grass and led to mortality. This is not a finding of the model nor are some of the variables related to sea grass degradation (e.g. fewer hard clams and food web shifts)."

- This bullet is a Key Finding that presents the data aggregated for this project (both generated and secondary) in summary form as context for the analysis and conclusions presented in later form. The exceedances and thresholds listed are instances and observations of degraded ecosystem condition. They are not specific to seagrass or its mortality. Findings of the Index of Eutrophication are reported in subsequent Key Findings bullets.

PAGE 9 OF TAC COMMENTS (TO PAGE 13 OF THE REPORT)
"Third bullet: This needs clarification. Sea grass response "to what" is highly degraded. True, sea grass abundance and vitality were shown by project monitoring to be declining over time in the field studies. However they are but one set of variables among many in the model for assessing nutrient impacts. It's unclear what factors seagrass is responding to. Other stressors not included in this study are physical and mechanical impacts from boat traffic and bulk heading effects causing the loss of habitat. These variables were not included in the model nor studied in this project."

- This Key Finding is revised and placed into greater context. The project objectives do not include boat traffic, bulkheading, and many other variables, and this is acknowledged but Key Findings must focus on the findings of the project rather providing speculation or irrelevancies.

PAGE 10 OF TAC COMMENTS (TO PAGE 13 OF THE REPORT)
"Fourth bullet: "Data availability limits its power." What is the source of the variability, mentioned here only in passing, but discussed in much more detail within the body of the report. Until the researchers address these scientific concerns it's unclear whether the model outputs are accurate or significant. Understanding the limitations of the data inputs and model outputs will determine whether the Index of Eutrophication is ready for use with acceptable accuracy for environmental management purposes."

- It is not clear what variability and scientific concerns the TAC refers to here. Key Findings are necessarily brief summaries, details of which are included in the report. We are confident the results of the project are as accurate as possible given the limitations, which have been described in detail. It is not clear to us from the TAC comments what constitutes "acceptable accuracy for environmental management purposes".

PAGE 10 OF TAC COMMENTS (TO PAGE 13 OF THE REPORT)
"Fifth bullet: These overall scores and statements about declining eco-health leave out the more detailed discussion of data limitations in text which highlight that due to data paucity of certain

variables in different place and years the index may have different scores based only a few of the variables (e.g. there is no eel grass or brown tides in north)."

- Please define 'eco-health'. Given the complexity of the project and the multitude of datasets, indicators, responses etc, we want to ensure that our response accurately addresses the TAC concerns. We thoroughly document limitations associated with the datasets and outline the basis for the Index of Eutrophication. More detailed discussion is included in the main chapters of the report.

PAGE 10 OF TAC COMMENTS (TO PAGE 13 OF THE REPORT)

Sixth bullet: When a model plateaus and variability increases it usually indicates a problem with either data quality, model imbalances (weighting or scaling of variables), or other factors external to the model (stressor data not included in model). This variability should be explored mathematically by evaluating data sets and modeling parameters (equations). This analysis should be done before modeling scores are reported above, as it's unclear if index scores outputs are meaningful.

- Please recall that the Index of Eutrophication is a quantitative assessment tool based on comparing observations to defined thresholds, but it is not a predictive model, nor was it designed to be, nor was it specified to be so in the QAPP. The statements regarding model behavior do not apply to the types of tools exemplified by the Index of Eutrophication.
- We have however, analyzed the results of the Index of Eutrophication statistically, and found that the declines over time in the central and south segments and the increase in the north segment were all significant, as we report. Further, the Index of Eutrophication exhibited significant non-linear (i.e. logarithmic) behavior as nutrient loading (both total nitrogen and total phosphorus) increased.

PAGE 10 (OF TAC COMMENTS TO PAGE 14 OF THE REPORT)

- Fourth bullet on page 10. These comments are a repeat of the TAC comments on pages 8 and 9. These comments have already been addressed above and will not be addressed again here.

PAGE 10 (OF TAC COMMENTS TO PAGE 14 OF THE REPORT)

- Fifth bullet on page 10. These comments are a repeat of the TAC comments on page 9 (Nutrients). These comments have already been addressed.

PAGE 10 OF TAC COMMENTS (TO PAGE 14 OF THE REPORT)

"Last bullet: If so, is there causal linkage to biota or are there other more important variables?"

- This Key Finding has been placed in broader context.

PAGE 10 OF TAC COMMENTS (TO PAGE 16 OF THE REPORT)

"Next to last paragraph on the page, last 5 sentences about the manuscript's organization: Based on these five statements, I expect the other sections of the report to discuss 1) loads, 2) stressors and responses, 3) index development and current condition, 4) eutrophication, and 5) conclusions and management recommendations. I expect the sections to be organized consistently (e.g., intro, methods, results, etc.). Also, eutrophication extent is identified redundantly as a goal of component 2 and 4."

- Attention has been paid in the revision to the organization of the report and its Chapters, the content included and its placement.

PAGE 11 OF TAC COMMENTS (TO PAGE 17 OF THE REPORT)

"The report should discuss how the specific candidate indicators were selected. Were any minimum criteria applied for indicators?"

- We specify: "It uses ~20 (rather than 5) indicators selected for based on their responsiveness to eutrophication as demonstrated in the literature and specified in the project Quality Assurance Project Plan (QAPP)"

PAGE 11 OF TAC COMMENTS (TO PAGES 18 AND 61 OF THE REPORT)

These sections describe the calculation process of the biotic index of eutrophication for the estuary. This process includes calculations of "component index scores" using "raw scores" and "weighted scores" for all 21 indicators, calculated for six components using data collected each year (1989 through 2010 and 2011) in 3 segments of the estuary. This process is complicated, thus a simplified "step by step" diagram/schematic providing a big picture of how the final "overall" index for the estuary was developed would be helpful.

- We have revised the description of the approach, methodology, and calculation of the Index of Eutrophication for BBLEH.

PAGE 11 OF TAC COMMENTS (TO PAGE 22 OF THE REPORT)

Last complete paragraph on the page (before INTRODUCTION): I'm not sure what this paragraph is trying to say; it looks like a statement taken from a proposal. As the final paragraph of the Executive Summary, I think this paragraph should provide 1) a summary of the key recommendations for addressing the bay's eutrophication via nutrient management or other actions or 2) the key next step (e.g., address one or two primary data gaps re eutrophication, etc). This paragraph has been significantly revised and broken into two paragraphs that 1) summarize the main messages discussed in the Key Findings and Executive Summary and 2) provide recommendations based on addressing the main issues identified as a result of this project.

PAGE 11 (OF TAC COMMENTS TO PAGE 23 OF THE REPORT)

Fourth bullet on page 11. "Extensive studies conducted on the estuary during the past two decades have documented these problems" is then followed by citations of four sources written by one of the authors of the report (Kennish). I would imagine that there are studies by other authors and it would be more credible to include some of those sources as well."

- We have revised the report as follows: "Extensive studies, peer-reviewed publications (including references therein), and technical reports on the estuary during the past two decades have documented these problems (Bricker et al., 1999, 2007; Bologna et al., 2000; Kennish, 2001a; Lathrop and Bognar, 2001; Seitzinger et al., 2001; Gastrich et al., 2004; Kennish and Townsend, 2007; Kennish et al., 2007a, b; 2008, 2010, 2011; Lathrop and Haag, 2007; Kennish, 2009; Barnegat Bay Partnership, 2011; Fertig et al., 2012; Kennish and Fertig, 2012)."

PAGE 11 (OF TAC COMMENTS TO PAGES 24-27 OF THE REPORT)
Fifth bullet on page 11. "Statement of the Problem and "Scope of Ecosystem Change": these two sections are redundant; they should be combined and shortened."

- We disagree. The "Statement of the Problem" describes the ecological problems in the estuary, notably those linked to eutrophication and sets the stage for later sections in the report, especially related to biotic responses/impacts. This is necessary to explicitly place this in context with the rest of the report. The next section "Scope of Ecosystem Change" specifies the magnitude of change. So, it is different. In addition, the "Scope of Ecosystem Change" is less than two pages. These two sections together are less than five pages in a report that is ~260 pages.

- We moved the hard clam description from the "Statement of the Problem" section to the "Scope of Ecosystem Change" section because the hard clam description provides more accurate information on the scope of change.

PAGE 11 (OF TAC COMMENTS TO PAGE 26 OF THE REPORT)
Sixth bullet on page 11. "Since 2004, eutrophy has generally worsened in much of the BB-LEH, and the condition of seagrass habitat has significantly degraded." How is eutrophy defined? Increased chlorophyll a, low dissolved oxygen levels, excessive diurnal swings in dissolved oxygen, plant biomass or is the conclusion based on seagrass decline? Please add definitions to the report."

Eutrophy refers to a waterbody impacted by eutrophication.

- Eutrophication is defined as the process of nutrient enrichment and increase in the rate of organic matter input in a waterbody leading to an array of cascading changes in ecosystem structure and function such as decreased dissolved oxygen levels, increased microalgal and macroalgal abundance, occurrence of harmful algal blooms (HABs), loss of seagrass habitat, reduced biodiversity, declining fisheries, imbalanced food webs, altered biogeochemical cycling, and diminished ecosystem services.

PAGE 11 (OF FOR TAC COMMENTS TO PAGE 27 OF THE REPORT)
Seventh bullet on page 11. "Seagrass now covers a 5260-ha area of the BB-LEH estuarine floor (Lathrop and Haag, 2011). This means that seagrass covered about 20% of the bay bottom. Does this include widgeon grass in the northern part of BB? What percent of BB-LEH could/should support seagrass?"

The 5260-ha seagrass area in the estuary noted by Lathrop and Haag (2011) includes seagrass cover in the northern segment too. The northern segment supports both widgeon grass and eelgrass, although widgeon grass is far more abundant there.

It is currently unknown what percentage of the estuary could or should support seagrass. At one time, there was much more eelgrass located along the western side of the estuary as well, but these beds have largely disappeared. This TAC comment has little, if anything, to do with development of an Index of Eutrophication for the estuary.

PAGE 11 (OF TAC COMMENTS TO PAGE 27 OF THE REPORT)
Eighth bullet on page 11. "Designated as moderately eutrophic in the early 1990's, BB-LEH was later reclassified as higher eutrophic in the late 1990's, a designation reconfirmed in 2007. Bricker's approach was very subjective and heavily weighted towards brown tide blooms. The reason for this project was to develop an index appropriate for BB-LEH."

The index that is developed by this project is quantitative and appropriate for BB-LEH. The description of Bricker's report is to illustrate comparisons.

PAGE 11 (OF TAC COMMENTS TO PAGE 29 OF THE REPORT)
Ninth bullet on page 11. "Barnegat Bay functions as three separate waterbodies and would be expected to have different retention times. How does this factor into the overall eutrophication index for the north, central, and south?"

Characterizing Barnegat Bay as three separate waterbodies is incorrect, since they are in fact connected geographically and there is exchange and interconnectedness among the three areas. This is a technicality. Due to the geomorphology, these three areas do display different characteristics and thus do need to be considered separately.

Barnegat Bay-Little Egg Harbor would be expected to have different residence times for different segments of the estuary because of the location of the two major inlets (Barnegat Inlet and Little Egg Inlet) and how far removed a particular location is from these sites. Certainly more hydrographic studies are needed to refine water residence time measurements for the different segments of the estuary. Such studies are underway. The residence time attributed to Guo et al. (1997, 2004) provided a general value for residence time of the estuary.

PAGE 12 (OF TAC COMMENTS TO PAGE 30 OF THE REPORT)
First bullet on page 12. "Nonpoint source inputs account for almost all of the nitrogen entering the estuary. The role of point source of N has not been evaluated. Chlorine used daily for 2 hours at the plant interacts with organic tissues and forms chloramines, the fates and fluxes of which are presently unknown…"

- This TAC comment falls outside the bounds of the QAPP specifications and has no relevance to the development of the Index of Eutrophication for the estuary.

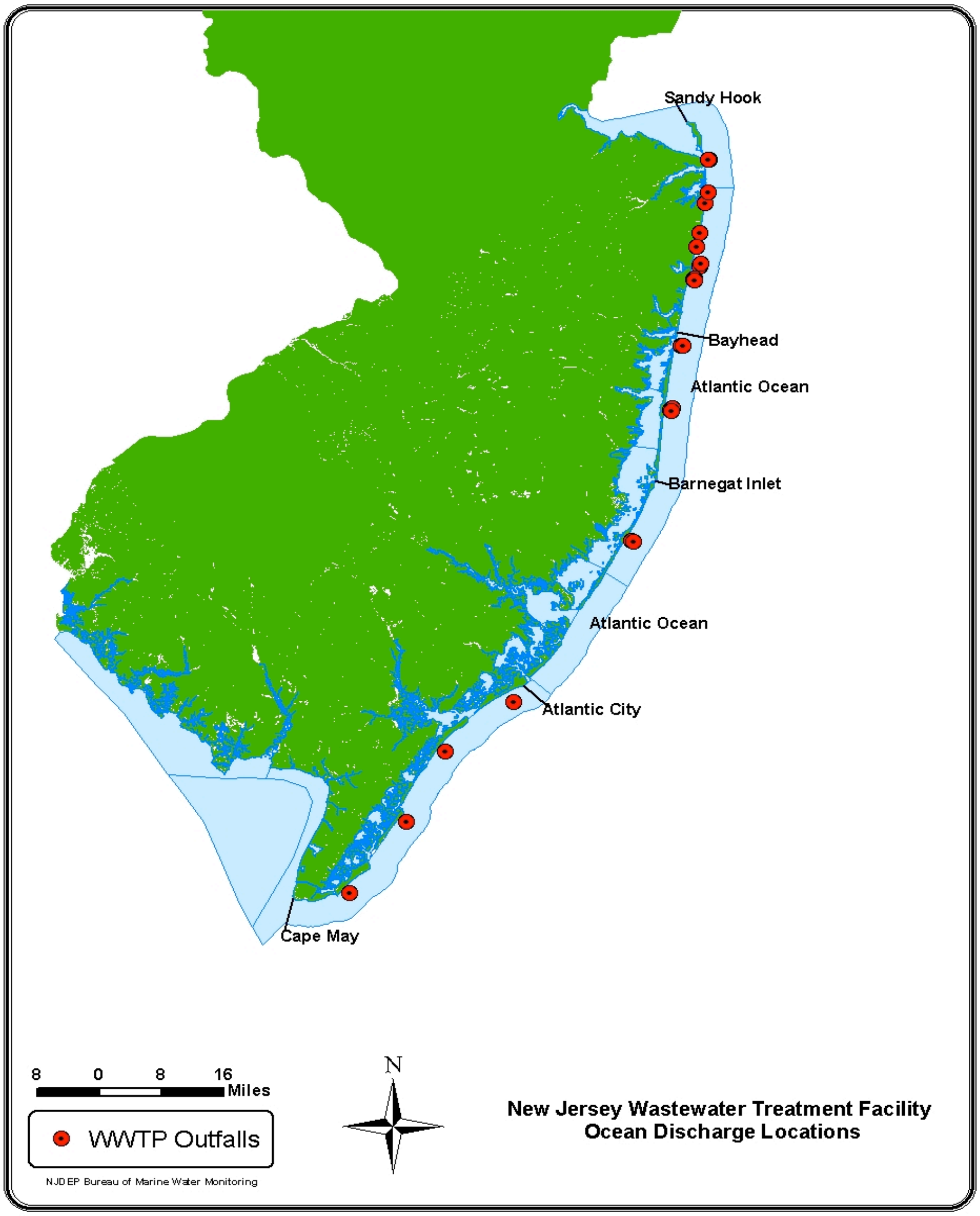
- We do agree, however, that since the NJDEP regulates point source pollution discharges in the State, it is the responsibility of the NJDEP to assess possible nitrogen inputs to Barnegat Bay from the OCNGS. To our knowledge that has not been done to date.

PAGE 12 (OF TAC COMMENTS TO PAGE 30 OF THE REPORT)

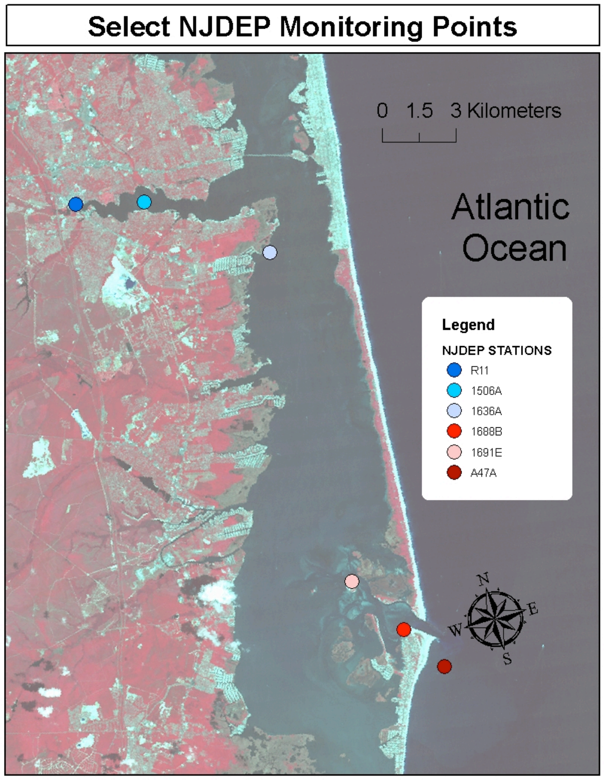
Second bullet on page 12. TAC comments are that the nearshore ocean may be an important source of nitrogen entering Barnegat Bay through Barnegat Inlet. "Guo and Psuty (2000) and Guo et al. (2004) suggest substantial N may enter the estuary through inlets based on inlet N measurements. Guo et al. 2004 makes additional arguments in support of the ocean as a source of N from offshore sewage discharges from an examination of current vector diagrams."

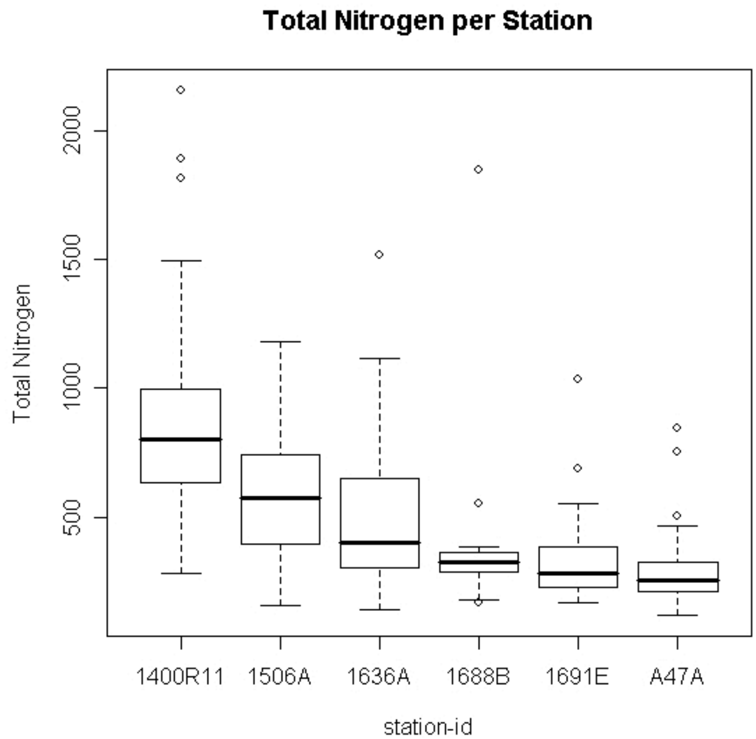
- First off, Guo and Psuty (2000) and Guo et al. (2004) do not provide data that measures or confirms entry of the treated sewage wastewaters into Barnegat Bay via Barnegat Inlet. This TAC comment does not provide any actual measurement or concentration of nutrients entering the estuary that are derived from these wastewaters or from ocean waters in general that can be assessed. It also does not mention that the areas where the wastewaters discharge to the nearshore ocean are located 8-10 miles north and south of the inlet, and hence are subject to great volumes of dilution (see graphic below).

- Please note, nitrogen data collected by the NJDEP at stations A47A and 169IE (second figure below) near the inlet do not indicate elevated measurements that would be expected if high concentrations of nitrogen were entering the bay from the nearshore ocean through the inlet.



- Secondly, we have analyzed a significant database on the source and exit point of nitrogen in the Barnegat Bay system using NJDEP water quality data. The results are shown below which is contrary to the TAC statements made above. More specifically, we examined the total nitrogen concentrations in water samples collected by the NJDEP over a ~10-year period at six NJDEP water quality monitoring stations, two in lower Toms River, one just south of Toms River, two in the bay just inside of Barnegat Inlet and one in the nearshore ocean near the inlet (see figure below). These water quality sampling stations were chosen to track the transport of nitrogen and the likely direction of nitrogen movement: either exiting or entering the bay. Box plots showing the results of the nitrogen analysis at these six stations are also given below, which clearly illustrate the likely source (Toms River) and exit point (Barnegat Inlet) of nitrogen in this system. These results are consistent with the USGS findings regarding nitrogen loading which indicate that Toms River is the major source of nitrogen entering Barnegat Bay. They also reveal that the inlet is the outwelling site for the nitrogen, not the site of major nitrogen entry from the coastal ocean.

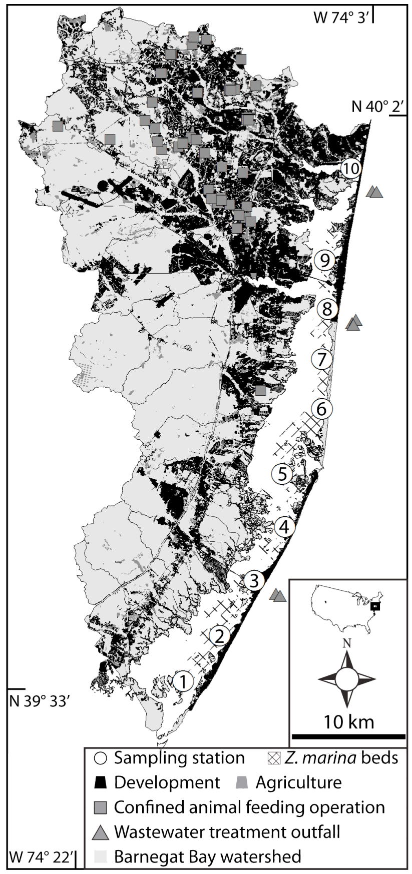




- Box plots showing concentrations of total nitrogen measured at six water quality sampling stations by the New Jersey Department of Environmental Protection over the period from 1995 to 2006. See figure above for station locations in Toms River, Barnegat Bay, and the nearshore ocean.

PAGE 12 (OF TAC COMMENTS TO PAGE 30 OF THE REPORT)
Third bullet on page 12. “Confined animal feeding operations (52 total) cover a very small area of the watershed. With only one exception of a centrally located feeding operation in the watershed, all are located in the northern portion of the watershed. Citation?

This statement and associated figure (see below, included in the report) are published in Kennish and Fertig 2012, and shown above. The citation is as follows: Kennish, M. J. and B. Fertig. 2012. Application and assessment of a nutrient pollution indicator using eelgrass (*Zostera marina* L.) in Barnegat Bay–Little Egg Harbor estuary, New Jersey. *Aquatic Botany* 96: 23-30.



PAGE 12 (OF TAC COMMENTS TO PAGE 31 OF THE REPORT)
Fourth bullet on page 12. "Recommend including a table describing the physical and chemical characteristics of each segment of the estuary..."

This would be redundant to the pertinent physical and chemical characteristics already described in the text of the report starting at the bottom of page 34 and going to the end of page 37.

PAGE 12 (OF TAC COMMENTS TO PAGE 31 OF THE REPORT)
Fifth bullet on page 12. "Water quality: indicates several bases for high nutrients in the northern section. However, figure 5-2 seems to conflict with higher levels observed in the central section."

Figure 5-2 shows decadal mean concentrations of total nitrogen. Other figures indicate annual means. Nutrient concentrations fluctuate on a monthly to weekly scale. It is important to keep in mind relevant time scales when discussing water quality.

PAGE 12 (OF TAC COMMENTS TO PAGE 31 OF THE REPORT)

Sixth bullet on page 12. “I don’t know what the greatest impacts of the OCNGS are, because, as noted in the manuscript, the OCNGS effects have been so inconsistently assessed…Shouldn’t there be a more holistic assessment of the OCNGS effects?”

This comment has no relevance to the development of an Index of Eutrophication or the mandates of the QAPP.

Having stated the above, a comprehensive assessment of the OCNGS effects during the 1970’s can be found in the 5-volume, 316 (a) and (b) Demonstration Report of the Jersey Central Power and Light Company that was submitted to the NJDEP in 1978. This report provided the most detailed data on the impacts of the power plant during the 1970’s. Comparable investigations of power plant effects on biotic communities and habitats in the estuary were not conducted after completion of the 316 (a) and (b) report.

The NJDEP should have a copy of the 316 (a) and (b) report on the OCNGS because it was formally submitted to the agency in 1978.

A summary of the impacts of entrainment, impingement, thermal discharges, and biocide releases of the OCNGS can be found in the following publication: Kennish, M. J. 2001. State of the estuary and watershed: an overview. *Journal of Coastal Research*, SI32: 243-273. A more holistic assessment of OCNGS ecosystem effects is certainly warranted, however. Holistic assessment of the OCNGS falls outside the purview of this project, and in the domain of the regulatory authority of the NJDEP on the OCNGS. The OCNGS has operated since December 1969. We still do not know enough about the ecosystem response to its operation over the intervening 40+ year period. This is due in large degree to the fact that entrainment and impingement monitoring, as well as studies of thermal discharges and biocidal releases at the OCNGS have not been conducted concurrently with sampling and surveys of biotic communities, habitat, and water quality in Barnegat Bay and Little Egg Harbor that would enable effective and accurate assessment of cause-and-effect relationships. This has left a major data gap for understanding the overall impact of the OCNGS on the estuarine ecosystem.

PAGE 12 (OF TAC COMMENTS TO PAGE 31 OF THE REPORT)

Seventh bullet on page 12. “Other adverse effects on estuarine water quality include nonpoint source inputs of pathogens and other pollutants as well as bulkheading, dredging, and lagoon construction.”

This comment has no relevance to the development of an Index of Eutrophication and the mandates of the QAPP. Bulkheading, dredging, and lagoon construction impacts are not key indicators agreed to in the QAPP for development of an Index of Eutrophication. These elements should be the target of future research initiatives on the estuary.

The primary objective of the NEIWPCC project was to develop an Index of Eutrophication for the Barnegat Bay-Little Egg Harbor Estuary. To accomplish this objective, the approach (approved by all parties and covered in the QAPP) was to establish key water quality and biotic indicators of condition, which are specified in the QAPP. This project, as is true of all estuarine assessment projects, cannot cover 100% of environmental factors and indicators of condition, but is relegated to focus on the most important indicators to assess eutrophication. There is an ongoing effort to investigate other factors affecting the ecology of Barnegat Bay-Little Egg Harbor. This is reflected in the data gaps that remain to be filled and the efforts underway to fill them.

PAGE 12 (OF TAC COMMENTS TO PAGE 33 OF THE REPORT)
Eighth bullet on page 12. "Sections of this report are not consistently organized."

We have moved the Objectives section to the end of the Introduction. We have renamed section heads.

This report is not a science journal research article with the same format of sections from one component to the next: Abstract, Introduction, Methods, Results, Discussion, etc. For example, Component 2 provides a description of the indicators used in development of the Index of Eutrophication calculated in Component 3. This description feeds into Component 3, and the format of Component 3 also does not follow the standard format of Abstract, Introduction, Methods, Results, Discussion, etc. because of the subject matter. Similarly, the format of the other components of the report is also not organized consistently due to the nature of the subject matter and the objectives of the report. The current format reflects this.

PAGE 12 (OF TAC COMMENTS TO PAGE 33 OF THE REPORT)
Inserted "Each of these parameters will be examined and assessed for statistical validity and inclusion in the index development for the 1989 to 2011 period." This is inserted into Objective 4.

PAGE 12 (OF TAC COMMENTS TO PAGE 33 OF THE REPORT)
Tenth bullet on page 12. "Objective 5 was changed from what appeared in the QAPP, now says: "to generate…" instead "to develop" a biotic index.

Objective 5 has been changed to include the words "to develop" a biotic index.

PAGE 13 (OF TAC COMMENTS TO PAGE 34 OF THE REPORT)
First bullet on page 13. "Elsewhere in the report, the limitations on the data are documented. Using the existing data set, it is unlikely that any attempt to develop nutrient loading criteria, along with the appropriate error bars, would be technically justified."

It would be incorrect and disingenuous to not specify the limitations of this, or any, study. Therefore, we honestly examine and report the data that are used, the conclusions that can be drawn from them, and the associated limitations of the study. The scope of this study and report is bound by the QAPP. We note that the availability and intensity of data has increased over the study period. Despite the documented limitations of the datasets, it is not justified to conclude that no nutrient loading criteria can accurately be developed. The report has shown that

Eutrophication Condition decreases with increased nutrient loading to ~2,000 kg TN km^{-2} yr^{-1} and ~100 kg TP km^{-2} yr^{-1}, and that with additional increases in nutrient loading, Eutrophication Condition plateaued at a low level with increased variability.

"The data do not clearly support the suggestion that if we reduce the nutrient loading to a specific level the seagrass beds will rebound, hard clam recruit and populations will improve and sea nettles will disappear."

The same comment was made by many people more than 30 years ago when attempts were being made to reduce nutrient loading to Tampa Bay. Reduction in nutrient loading was accomplished there and that system showed dramatic ecosystem improvement through time as a result. The prevailing science for dealing with a eutrophic estuary is first and foremost to reduce nutrient loading. This is the prevailing science. It is true that attempts to reduce nutrient loading may not succeed. Just look at the case of Chesapeake Bay. However, what other option would the TAC recommend here? Stay the course? Wait for the restoration of 10 of 2700 stormwater basins in the watershed to take effect?

Ultimately, one goal of this project, as documented in the QAPP and report, is to develop an index to assess the condition of eutrophication in Barnegat Bay-Little Egg Harbor based on the assembled database. Whether the index or assembled database is ultimately used in the future depends on decisions by the NJDEP and USEPA. Forging numerical nutrient loading criteria may be one outcome of the index work.

PAGE 13 OF TAC COMMENTS (TO PAGE 35 OF THE REPORT)
Second bullet. "Component 1, "Watershed Nutrient Loading Loading." Note the text duplication."

- This has been corrected.

PAGE 13 OF TAC COMMENTS (TO PAGE 35-39 OF THE REPORT)
"The report states: "A numeric scoring system was used that computes an index value from key water quality and biotic indicator measurements in each of the three estuary segments for years sampled during the 1989 to 2011 period". This statement is misleading if the index scores for some of the components were calculated based on data collected during only one year period (e.g., benthic invertebrates). In the discussion of components 1 through 5, it becomes clear that different datasets were used to evaluate different biotic responses. (e.g., data on seagrass beds were collected from 2004-2006 and from 2008-2010, data on epiphytes were collected from 2009-2011, while hard clam and benthic invertebrates data were collected in 2001). On page 140, Table 3-2 nicely summarizes all datasets used for evaluation of different indicators. It would be helpful to refer to this table on page 35."

- The statement is revised to indicate available biotic measurements and Table 3-2 is referred to aid the reader in identifying which data are available when.

PAGE 13 (OF TAC COMMENTS TO PAGE 36 OF THE REPORT)
Eighth bullet on page 13. "The final report should include citations of field and lab methods and QA/QC and any modifications that were made. It should also cite the QAPP."

All of the field and lab methods used in the project followed the mandates of the QAPP verbatim, and the QAPP is cited in the revised report and in this document of responses. To include statements of field and lab methods in the report that are also cited in the QAPP is redundant.

PAGE 13 OF TAC COMMENTS (TO PAGE 36 OF THE REPORT)
"Estuarine Biotic Responses: Secondary water quality data were used in this investigation. Describe how these data were screened for use. In particular, what temporal and spatial coverage criteria were used, if and how outliers were determined, what the criteria were for age of data, comparable sampling and laboratory method criteria, etc. Representativeness of the secondary data also should have been evaluated and needs to be stated. Some of the secondary was collected in a targeted or focused manner, i.e. to find problems, and is not appropriately used in an index that is determining overall condition. This information should be summarized in a table along with source citations for the data."

- All data were evaluated with respect to the study and sampling design, QA/QC to 1) identify spatial coverage and temporal resolution and 2) compare the data availability to the needs of the current project, and 3) conduct QA/QC tasks as described in detail in the methods section of Chapter 2. Caveats and limitations are fully described in the respective chapter.
- Please clarify what the TAC means by "what the criteria were for age of data". The scope of the project is 1989-2010 with 2011 data used for verification. Data outside these years cannot be considered for inclusion in this project.
- Indicators with data found to have serious limitations are discussed in the section regarding the limitations of the database. This detailed section is located in Chapter 2 and Chapter 3, rather than in the summary/overview section included in Chapter 1. Representativeness of data was a serious problem for a variety of indicators, including dissolved oxygen (which was measured *in situ* quarterly rather than continuously from data sondes though dissolved oxygen fluctuates cyclicly daily with photosynthesis rates and temperature), Secchi depth (which hit bottom and is thus considered 'censored' data, and others. These limitations are described in full in the report and need not be repeated here. Table 3-2 indicates which data are available when and for which segments.

PAGE 14 (OF TAC COMMENTS TO PAGE 36 OF THE REPORT)
First bullet on page 14. "Shellfish data were collected at regular bi-monthly intervals from June to November. However, the text indicates that the DEP collected data from July 16 through August 31, 2001. Please clarify or correct."

The shellfish data collected in the project refers to field observations by a diver of hard clam and bay scallop occurrence at each field station on each sampling date. The shellfish data collected in 2001 by the DEP refers to the data reported by Celestino (2003) for the 2001 hard clam survey in Little Egg Harbor.

PAGE 14 OF TAC COMMENTS (TO PAGE 37 OF THE REPORT)
First bullet: "Phytoplankton section describes the Department's remote sensing program which started in 2011. How were the data used? Were only water samples collected in the blooms

used? Also, other reports published by DEP and USEPA indicated other blooms of green and red tides occur periodically and in other parts of the bay beside LEH. Why wasn't this data set used as well in HAB part of index?"

- Chlorophyll *a* measurements from the remote sensing analysis are included in the reported values documented throughout Component 2 and Component 3.
- Analysis of additional indicators not specified in the QAPP is beyond the scope of work for this project.

PAGE 14 OF TAC COMMENTS (TO PAGE 38 OF THE REPORT)

""Methodology Elements, Component 3" subsection states that: "For ecosystem pressures, the metrics include total nitrogen loading, and total phosphorus loading". This is not consistent with a statement made in "Ecosystem Pressures" section on page 43, which states "Water residence time and total nitrogen loading are the two key indicators of ecosystem pressure used in this project." On page 39, the report also states that "Such an index would combine ecosystem pressures (nutrient loading and water residence time), ecosystem state, and biotic responses. Please clarify."

- Water residence time was considered for but ultimately not included in the Index of Eutrophication. Therefore, mention of water residence time has been omitted from the statements from those pages noted.
- We note that total nitrogen and total phosphorus loadings are the two key indicators of ecosystem pressure. Qualitatively, however, we note that water residence times may also play a role in the susceptibility of the estuary to ecosystem pressures. Water residence time in the estuary ranges from 24 days in winter to 74 days in summer, when eutrophication is most pronounced (Guo et al., 2004). Long residence times are important because it leads to retention and recycling of nutrients rather than their dilution or export associated with faster rates of oceanic exchange and flushing.

PAGE 14 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)

Biotic Index Development: "An important goal of this project is to develop an effective and useful index of eutrophic condition for the BB-LEH estuary." The actual objective (stated in the QAPP) was: "To develop a biotic index of estuarine condition using water quality and biotic indicators to assess eutrophication, impairment, and overall ecosystem health of the BB-LEH estuary…." This section only seems to cover how the index was applied to the segments, so a discussion should be included of the application to the entire system. Can the index as currently developed be used to assess overall ecosystem health?

- The objective stated in the QAPP is used rather than the paraphrasing that was quoted in the TAC comments. We note that the assessment for each segment can be compared to provide an application to the entire system.

PAGE 15 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)

First bullet: "Biotic Index Development: The QAPP (pg. 28) stated: "These major groups (estuarine organisms) will be monitored across the study period to determine when numeric shifts occur in abundance, …., which will be correlated with nutrient loading levels to document the threshold points and levels of biotic decline." How were these threshold points determined and where in the report are they shown?"

- As noted in Chapter 3, “An indicator’s thresholds can be considered to be values for that indicator that mark some type of change in other (response) variables. Thresholds are determined and defined through examination of: (a) the literature, (b) analysis of available data for BB-LEH, (c) Best Professional Judgment, and (d) some combination of a-c.” The thresholds for each indicator are shown in Tables 3-8, 3-10, 3-11, and 3-12.

PAGE 15 OF TAC COMMENTS (TO PAGE 39, 55, 60, & 67 OF THE REPORT)
“"Gleason's D value" is used as one of matrixes for benthic invertebrate response component. Term "Gleason's D value" is not defined in the document.”

- In the Executive Summary, where mentioned in Chapter 2 and where first mentioned in Chapter 3, we note: “The Gleason’s D Index for infaunal and epifaunal species was calculated as: D = (total # species)/(natural log of total abundance). All species reported at a station were included.”
- Also, where mentioned in Chapter 2, we note: “the salinity-normalized Gleason’s Index was calculated as the ratio of the measured and expected Gleason’s D indices, reported as a percent (Paul et al., 1999). The expected index is calculated: PEXP_GL3 = GLEASON3/(4.283 - 0.498*sal + 0.0542*sal^2 - 0.00103*sal^3)*100 where ‘sal’ is the bottom water salinity.”

PAGE 15 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)
First bullet: “Biotic Index Development: The QAPP (pg. 28) stated: “These major groups (estuarine organisms) will be monitored across the study period to determine when numeric shifts occur in abundance, …., which will be correlated with nutrient loading levels to document the threshold points and levels of biotic decline.” How were these threshold points determined and where in the report are they shown?”

- As noted in Chapter 3, “An indicator’s thresholds can be considered to be values for that indicator that mark some type of change in other (response) variables. Thresholds are determined and defined through examination of: (a) the literature, (b) analysis of available data for BB-LEH, (c) Best Professional Judgment, and (d) some combination of a-c.” The thresholds for each indicator are shown in Tables 3-8, 3-10, 3-11, and 3-12.

PAGE 15 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)
Second bullet: “Biotic Index Development: The QAPP (pg. 28) stated: “They (biotic data) will be examined and assessed for statistical validity and inclusion in the index development for the 1989 to 2011 period.” The actual statistical procedures and outcomes should be included in the report.

- The approach and statistical results for this examination of statistical validity has been submitted to the TAC previously through the progress reports. Appendix 3-2 contains information regarding additional data examined for potential inclusion in the Index of Eutrophication. Given the complexity and quantity of datasets and data included in this project it would be confusing and inappropriate to include in the report datasets or data that were not ultimately included in the Index of Eutrophication. However these are included in the Appendix to document the full extent of the substantial analysis and examinations that occurred for this project.

PAGE 15 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)
Third bullet: “Validation Dataset (2011): Describe the validation procedures. What statistical comparisons were used for validation?”

- The validation dataset and process are more fully described in Component 4.

PAGE 15 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)
First bullet: “ “Such an index would combine ecosystem pressures (nutrient loading and water residence time), ecosystem state, and biotic responses.” What is the basis for using water residence time as an ecosystem pressure? Also, if you are going to examine data by segment, shouldn’t the water residence time be examined by segment?   Residence time varies among segments; wouldn't it also be affected by the tides (spring vs neap, local sea levels which change with storms (hurricanes, northeasters), and OCNGS operation, which varies seasonally?”

- Water residence time cannot be included in the index. The quoted statement is revised to omit reference to residence time.

PAGE 15 OF TAC COMMENTS (TO PAGE 39 OF THE REPORT)
Second bullet: “Component 4: Validation Dataset (2011) for Eutrophication Assessment. The objective identified here is different from the statement in the Executive Summary. “

- The QAPP (p. 20) states: “In Component 4, additional sampling and data analysis will be conducted in 2010 to assess the current status of eutrophication of the estuary. This component will also provide information to validate biotic responses in previous years.” Validation was done during 2011 due to the agreed-upon revised timeline of the project. The objective and summary described here matches that of the QAPP.

PAGE 16 (OF TAC COMMENTS TO PAGE 42 OF THE REPORT)
First bullet on page 16. “The QAPP states that shellfish (bay scallop) data will be collected while in the field. Where are these data in the report?”

- These data are not included in the index calculations or development. They are stored in an archived database that is accessible to the TAC.

PAGE 16 (OF TAC COMMENTS TO PAGE 42 OF THE REPORT)
Third bullet on page 16. “Please clarify statements such as “modification with perpendicular transects.”

- The one modification of the SeagrassNet approach in the field was to establish sampling transects perpendicular to shore rather than parallel. This was done to identify seagrass and other differences along a clearly defined depth gradient in the system.

PAGE 16 (OF TAC COMMENTS TO PAGE 43 OF THE REPORT)
Fourth bullet on page 16. “Define eutrophication (by the author’s definition).”

- The definition of eutrophication is provided in the response to TAC comments on page 3. It is also included in the report. It is based on published peer-reviewed literature (Nixon, 1995; Paerl et al., 2010; Kennish and de Jonge, 2011; and others). It is repeated below.

- Eutrophication is defined as the process of nutrient enrichment and increase in the rate of organic matter input in a waterbody leading to an array of cascading changes in ecosystem structure and function such as decreased dissolved oxygen levels, increased microalgal and macroalgal abundance, occurrence of harmful algal blooms (HABs), loss of seagrass habitat, reduced biodiversity, declining fisheries, imbalanced food webs, altered biogeochemical cycling, and diminished ecosystem services.

- The indicators selected for index development in the project are those that provide the data necessary to assess eutrophic condition of the waterbody.

PAGE 16 OF TAC COMMENTS (TO PAGE 43 OF THE REPORT)
Second bullet: "Should precipitation, temperature, and/or turbidity be a pressure given they affect "alternative states." Could the number of boats registered within the water be a pressure?"

- The meaning of the TAC comment is not clear. Please clarify the usage of "alternative states." Boat registration is not a variable specified by the QAPP and cannot be examined by this project.

PAGE 16 OF TAC COMMENTS (TO PAGE 43 OF THE REPORT)
Third bullet: "Ecosystem State – Water Quality: The summary of current conditions should be consistent with the thresholds selected (annual average, annual median, growing season average). Based on the review of literature provided, none employ the maximum values."

- Maximum values are included to document the range of each indicator. This is important as the mean, median, range, variance, variability, and other descriptive statistics are utilized in a variety of statistical analysis throughout the report. It is not clear from the TAC comments for what purpose the literature review served – what articles were examined and what information was being sought? What comparisons were being made?

PAGE 16 OF TAC COMMENTS (TO PAGE 43 OF THE REPORT)
Fifth bullet: "Please clarify how the accuracy of diver estimated percentages were assured."

- Photographic records were used to ensure diver estimated accuracy.

PAGE 16 (OF TAC COMMENTS TO PAGE 43 OF THE REPORT)
Seventh bullet on page 16. "Please clarify what is meant by haphazardly tossing a quadrat into a sampling system."

Haphazardly in this case refers to tossing the quadrat randomly on a seagrass bed.

PAGE 16 (OF TAC COMMENTS TO PAGE 45 OF THE REPORT)

Twelfth bullet on page 16. "Indicates that Twilley documented 25-cm thick bloom-forming macroalgae. Since his work was conducted in Chesapeake, it might be better to delete "In the nutrient enriched waters of this coastal lagoon" or at least change it to read Chesapeake Bay."

Revision has been made to the second paragraph on page 65 of the report as follows. "In these systems, bloom-forming macroalgal species have been observed to form dense canopies more than 25-cm thick overlying seagrass beds, which block light transmission to the beds. Twilley et al. (1985), working in Chesapeake Bay which is a much larger estuarine system, has shown that macroalgal canopies can be detrimental to seagrass beds in deeper systems. As the algal standing stocks increase, shading reduces the photosynthetic oxygen production of seagrass plants, causing diebacks (Twilley et al., 1985; Hauxwell et al., 2001, 2003; Lee et al., 2007; Ralph et al., 2007)."

PAGE 16 (OF TAC COMMENTS TO PAGE 45 OF THE REPORT)
Thirteenth bullet on page 16. "It appears that macroalgae sampling was limited to seagrass beds in the south and central segments. As this is a parameter included in the light availability factor, how is this factor addressed in the northern segment or other areas without seagrass beds."

Macroalgal percent cover data were collected in the north segment during sampling in 2011. No macroalgal sampling was conducted in the north segment during the 2004 through 2010 period. Similarly, no seagrass data were collected in the north segment during this period. Hence, there are no data to assess macroalgae effects in the northern segment during this period.

We did not study macroalgae cover outside of seagrass beds because the objective of the Light Availability component used in developing the Index of Eutrophication was to determine the effect of macroalgal cover as a factor attenuating light to the seagrass beds. Since macroalgae are part of a drifting community in bare bottom areas and the target was to assess effects on seagrass beds, no measurements of macroalgal blooms were collected outside of the seagrass beds.

PAGE 16 (OF TAC COMMENTS TO PAGE 45 OF THE REPORT)
Fourteenth Bullet on page 16. "What percent cover had an initial effect on the seagrass based on the literature? Based on this section, 59% coverage does not impact the SAV/ecosystem. This parameter and percent value ranges need to be examined and linked to literature based on values (i.e., on an empirical basis)."

As noted above, there is no universal – or even commonly used – definition of a macroalgal bloom. In addition, there are really few standard methods for even measuring macroalgal abundance. Two of the accepted standard methods in the scientific community are macroalgal areal cover and biomass (Peggy Fong, University of California Los Angeles, personal communication). We have provided a peer-reviewed and accepted method of assessing macroalgal bloom occurrence in the estuary.

Percent areal cover is one method of determining macroalgal abundance and bloom occurrence. Our study documented bloom occurrence by using measures of macroalgal areal cover (i.e., macroalgae areal cover of 60-70% was considered 'Pre-Bloom', 70-80% was considered 'Early Bloom', and >80% was considered 'Full Bloom' conditions; Kennish et al., 2011). It did not measure the occurrence of seagrass bed damage at each category of macroalgal areal coverage. The goal was to determine if bloom occurrence was increasing, decreasing, or remaining unchanged over the study period. The literature base is clear on the impact of macroalgal blooms and damage to seagrass beds. As noted by Burkholder et al. (2007), in one of the most detailed reviews of seagrasses and eutrophication impacts, stated that "the most common mechanism…for seagrass decline under nutrient over-enrichment is light reduction…through algal overgrowth and epiphytes and macroalgae in shallow coastal areas, and phytoplankton in deeper coastal waters." The work is corroborated by others (e.g., Valiela et al., 1997; de Jonge and Elliott, 2001; McGlathery, 2001; Burkholder et al., 2007; McGlathery et al., 2007; Anderson et al., 2010; Fong et al., 2010).

Key Papers (Macroalgal Blooms and Seagrass Degradation):

Valiela, I., et al. 1997. Macroalgal blooms in shallow estuaries: controls and ecophysiological and ecosystem consequences. *Limnol. Oceanogr*. 42: 1105-1118.

McGlathery, K. J. 2001. Macroalgal blooms contribute to the decline of seagrass in nutrient-enriched coastal waters. *J. Phycol.* 37: 453-456.

McGlathery, K. J., K. Sundback, and I. C. Anderson. 2007. Eutrophication in shallow coastal bays and lagoons: the role of plants in the coastal filter. *Mar. Ecol. Prog. Ser.* 348: 1-18.

Burkholder, J. M., D. A. Tomasko, and B. W. Touchette. 2007. Seagrasses and eutrophication. *J. Exp. Mar. Biol. Ecol.* 350: 46-72.

Kennish, M. J., B. M. Fertig, and G. P. Sakowicz. 2011. Benthic macroalgal blooms as an indicator of system eutrophy in the Barnegat Bay-Little Egg Harbor Estuary. *Bull. NJ Acad. Sci.* 57: 1-5.

PAGE 16 (OF TAC COMMENTS TO PAGE 45 OF THE REPORT)

Fifteenth bullet on page 16. "Much of the information presented in the first two paragraphs of this section is out of place and should be deleted; only information relevant to the methods need be included in the methods section."

The macroalgae section on page 43 of the report only includes two short paragraphs of relevant information in the Methods section.

"Several different types of methods are used to collect different data. I recommend subheadings to make clear the different types of data which are being collected."

Yes. Many types of indicator data are being collected, which is why subheadings listing the data being collected (e.g. 'Macroalgae Percent Cover') are used.

“Why are the authors using so many different measures of macroalgae? Why are so many measures needed for macroalgae?”

It is unclear what the TAC is referring to with this comment. The key measure of macroalgae is percent areal cover, which is an important indicator of light attenuation that contributes to seagrass decline. All of these measures are necessary to develop an accurate Index of Eutrophication (see page 69 of the report). These are critically important measures for this project.

PAGE 17 (OF TAC COMMENTS TO PAGE 45 OF THE REPORT)

First bullet on page 17. “The third and fourth paragraphs of the macroalgae section are excellent: they clearly present results in an organized manner. All of the sections should be similarly organized.”

Thanks.

PAGE 17 (OF TAC COMMENTS TO PAGE 46 OF THE REPORT)

Second bullet on page 17. “Benthic macroalgae are powerful drivers of change in water quality and seagrass habitat. Citation? Be careful with your choice of words: correlation does not equate with causality.”

We insert the following citations: Valiela et al. (1997), Seitzinger et al. (2001), McGlathery (2001), McGlathery et al. (2007), Burkholder et al. (2007), Anderson et al. (2010).

It is not clear what the TAC is referring to here, regarding correlation or causality. The quoted sentence does not include the words ‘correlation’ or ‘causality’. The quoted sentence states a general understanding that is well established in the literature (see citations inserted). The paragraph goes on to list a number of significant correlations (both positive and inverse) between macroalgae percent cover and other variables (e.g. dissolved oxygen, eelgrass biomass, etc.). These statements are correctly identified as correlations. Significance or lack thereof is clearly stated.

PAGE 17 (OF TAC COMMENTS TO PAGE 46 OF THE REPORT)

Third bullet on page 17. “Macroalgal blooms contributed in part to the decline of seagrass biomass in BB-LEH over the 2004-2010 period (Kennish et al., 2008, 2010, 2011).”

This sentence has been revised in the report. High resolution images of the seagrass beds in this project have shown the loss of seagrass habitat due to macroalgal overburden.

While the TAC comments have focused on the issue of macroalgal overburden and whether that is sufficient to attenuate or block light transmission to the seagrass beds, they have not targeted at all the similar, and perhaps even greater impact, of epiphytes on the seagrass blades which have been measured by Rutgers. These observations are also well established by peer-reviewed, published literature (e.g., Brush and Nixon, 2002; Hauxwell et al., 2003; Larkum et al., 2006;

Anderson et al., 2007 Burkholder et al., 2007; McGlathery et al., 2007). It is necessary to look at all components that result in the loss of light transmission to seagrass leaves. That would include suspended solids in the water column as well.

PAGE 17 (OF TAC COMMENTS TO PAGE 46 OF THE REPORT)
Fourth bullet on page 17. "It appears that macroalgae varies significantly from year to year. Based on the level of variability, is it reasonable to conclude a trend?"

Statistical analysis conducted on the frequency of macroalgae blooms indicates that indeed it is reasonable and statistically valid to conclude a trend of increasing frequency of macroalage blooms at multiple intensities of cover. Fertig et al. (In press) note that macroalgae 'Early Blooms' (70-80%) occurred twice during 2004-2006 and 17 times during 2008-2010 (chi square $p < 0.01$). Macroalgae 'Full Blooms' (>80%) occurred 12 times during 2004-2006 and 24 times during 2008-2010 chi square analysis $p < 0.05$)

Kennish et al. (2011) also note that there has been an increasing trend over the 2004-2010 period.

Macroalgal blooms must be monitored yearly to determine if this trend will continue.

Fertig, B., Kennish, M.J., and Sakowicz, G.P. In press. Changing eelgrass (*Zostera marina* L) characteristics in a highly eutrophic temperate coastal lagoon. Aquatic Botany. (2012) DOI: http://dx.doi.org/10.1016/j.aquabot.2012.09.004

PAGE 17 (OF TAC COMMENTS TO PAGE 47 OF THE REPORT)
Fifth bullet on page 17. Epiphyte Percent Cover. "The first four paragraphs of the Epiphyte Percent Cover section are interesting but out of place. The methods need to be located consistently with other sections."

The first four paragraphs of the 'Epiphyte Percent Cover' section of the report on page 64 have been moved to pages 28 and 29 in the 'Statement of the Problem' section.

PAGE 17 (OF TAC COMMENTS TO PAGE 48 OF THE REPORT)
Sixth bullet on page 17. "Epiphyte areal cover on seagrass leaves was determined by collecting the five longest…" Citation for this method?"

Miller-Myers, R. and R. W. Virnstein. 2000. Development and use of an epiphyte photo-index (EPI) for assessing epiphyte loadings on the seagrass Halodule wrightii. Pages 15-23, in: S. A. Bortone, (ed.), *Seagrass: Monitoring, Ecology, Physiology, and Management.* CRC Press, Boca Raton, Florida.

PAGE 17 (OF TAC COMMENTS TO PAGE 49 OF THE REPORT)

Seventh bullet on page 17. “What is the purpose/need for so many measures? What do they tell us?”

There are six component measures for developing an Index of Eutrophication. Within these six components, there are 20 indicators. These indicators were agreed to with the TAC, USGS, and Rutgers researchers. They are deemed to be necessary to effectively assess eutrophic condition. Certainly, the use of only one indicator (dissolved oxygen) does not accurately or effectively assess eutrophication or impairment of BB-LEH. This is the purpose of the NEIWPCC project. This study is focused on BB-LEH, not eelgrass losses in other systems.

PAGE 17 (OF TAC COMMENTS TO PAGE 49 OF THE REPORT)
Eighth bullet on page 17. “For instance, what is the timeframe (e.g., month, temperature, light intensity) when shoot density is normally highest during the year? The same information is needed for biomass, coverage, blade length, etc.”

Data presentation in the narrative, tables, and figures of the report clearly show that the biotic parameters vary temporally and spatially in the estuary. There is considerable variation from year to year. Nevertheless, clearly, year-after-year decline of eelgrass biomass does not indicate ‘normal’ or ‘unstressed’ condition.

PAGE 17 (OF TAC COMMENTS TO PAGE 49 OF THE REPORT)
Ninth bullet on page 17. “While this may be true, I don’t think this has been proven at this point in the document. After all, isn’t that the point of Component 3.”

We have moved the following statement to Component 3: “Results of this project show conclusively that eelgrass condition in BB-LEH has declined substantially through time and that the rate of decline is related to nutrient loading and associated symptoms of eutrophication.”

PAGE 17 (OF TAC COMMENTS TO PAGE 49 OF THE REPORT)
Tenth bullet on page 17. “While the research may show…This supports the need for the dynamic water quality/quantity modeling the Department is conducting through a contract with USGS in order to define the relationship between nutrient loading and productivity in the bay.”

While this modeling work is important in itself, there is a need to concurrently investigate and collect data on nutrient assimilation in biotic tissue, particularly in the benthos, and nutrient accumulation in bottom sediments. These data are generally lacking. Also, the relationship between nutrient loading and productivity in a coastal lagoon is problematic in itself, as is the relationship between nutrient loading and seagrass loss in a coastal lagoon. As noted by Robert W. Howarth (Cornell University, personal communication), “Nutrient pollution is a major cause of seagrass loss, but the response of lagoon ecosystems to nutrients in different than that of deeper, phytoplankton-based ecosystems. In the deeper ecosystems, primary productivity increases as a linear function of nitrogen loading, and this provides one of the key tools of understanding for managers. This is not the case for shallow seagrass-dominated ecosystems;

over a broad range of increases in nutrient loads, primary production remains at a relatively constant level (see also Borum and Sand-Jensen, 1996; Nixon et al. (2001). Yet seagrasses are shaded by phytoplankton (in systems with sufficiently long water residence times) and overgrown by epiphytes and macroalgae, leading to die-off of the seagrasses. These responses are not linear with regard to increased nutrient load, and tipping points in the response are seldom anticipated by environmental managers."

PAGE 17 (OF TAC COMMENTS TO PAGE 49 OF THE REPORT)
Eleventh bullet on page 17. "Return to previous levels of eelgrass biomass may be difficult to attain…Didn't eelgrass recover from wasting disease from throughout large parts of its range?"

Wasting disease does not equate to eutrophication, even though wasting disease continues to damage eelgrass beds up and down the coast. Few estuaries in this country have recovered from eutrophication because nutrient loading and enrichment of these systems have not been successfully addressed or managed in nearly all cases (see Burkholder et al., 2007; Duarte et al., 2009). If the stressor is not removed, the problem will persist in seagrass biotopes. Continue to develop coastal watersheds and continue to load coastal bays with nutrients above a tipping point, and seagrass will continue to degrade.

Wasting disease still occurs along the range of eelgrass distribution, causing significant mortality during certain years and in some areas. This is another cause of mortality, although it has never equaled the losses incurred during the 1930's.

Duarte et al. (2009) have clearly shown that even in those cases where the stressor is removed, the trajectory of recovery of impacted estuarine systems rarely follows the trajectory of decline. They asserted that, because of multiple shifting baselines, the restoration of coastal ecosystems to an idealized past reference status after removal of human-induced pressure is highly unlikely. They showed that for eutrophication restoration, for example, damaged ecosystems displayed convoluted trajectories of recovery not directly reversible to reference ecosystem conditions. The impacted system did not return to the original conditions tracking reversal trajectories as a result of broad changes in environmental conditions which significantly affected the ecosystem dynamics and restoration targets.

PAGE 18 (OF TAC COMMENTS TO PAGE 50 OF THE REPORT)
First bullet on page 18. "Which seagrass metrics are most important and can they be aligned as to which are affected by nutrients versus other stressors such as water temperature or human disturbance?"

Biomass and percent areal cover are the two most important seagrass metrics. Biomass reveals how much tissue mass of seagrass is present per unit area and, when measured over intervals of time, how much tissue mass has been gained or lost over a specified period of time. Percent areal cover indicates how much of the seabed is covered by seagrass. These parameters reflect on general water quality and sediment quality conditions. This pattern of biomass response with increasing nutrient concentrations in BB-LEH is similar to load-decline relationships described in the literature (e.g., Burkholder et al 2007). Percent areal cover change in seagrass beds of the estuary can be similarly linked to load-decline relationships described in the literature.

PAGE 18 (OF TAC COMMENTS TO PAGE 52 OF THE REPORT)
Second bullet on page 18. "The assessment of widgeon grass was added to ensure that the Eutrophication Index would work in areas with lower salinities that cannot support seagrass. It does not appear that this work was factored into the overall assessment. How much additional information would be required to incorporate?"

Seagrass sampling in the north segment was only conducted during 2011. Therefore, no validation dataset exists for widgeon grass in this segment. Ideally several years of seagrass sampling should be conducted in the north segment for incorporation into an index.

Page 18 (OF TAC COMMENTS TO PAGE 52 OF THE REPORT)
Third bullet on page 18. "Harmful Algal Blooms…The statement "not been monitored in the estuary since 2004, and thus no observational HAB montoring data are available over the past eight years" does not acknowledge the Department's use of remote sensing with follow-up monitoring and species identification."

Did the Department monitor for brown tide in BB-LEH after 2004? The narrative on page 52 of the original NEIWPCC report that discusses the lack of monitoring of HABS after 2004 is specifically in reference to monitoring for brown tide. As noted above and repeated here, Anderson et al. (1993) and others state that identification of brown tide with standard light microscopy is "uncertain," and therefore an inaccurate and unreliable way to identify and (certainly) one incapable of accurately quantifying brown tides. Two effective and accurate ways to detect and enumerate brown tide are the application of monoclonal-antibody techniques (Caron et al., 2003) or use of quantitative polymerase chain reaction (Popels et al., 2003), which enables the detection of cells at even extremely low concentrations. Light microscopy and related standard laboratory methods are not effective methods to measure or monitor for brown tide. What was the approach used by the Department to monitor, identify, and enumerate for brown tide after 2004? Did this monitoring differ from that of Gastrich et al., (2002, 2004)?

The TAC comment on page 18 for Harmful Algal Blooms (top of page) notes that the DEP used remote sensing with follow-up monitoring and species identification after 2004 to check for brown tide. What approach was conducted in the laboratory for brown tide identification? The use of standard light microscopy in the laboratory to identify and enumerate brown tide is a seriously flawed approach as documented by Anderson and others. The questions are these: What methods were used to identify and enumerate brown tide during phytoplankton bloom events after 2004? Which years were monitored and how many stations in the estuary were sampled? Was the sampling estuary-wide and statistically valid, both spatially and temporally? If routine monitoring for brown tide was not conducted in the field after 2004, then bloom events certainly could be missed because brown tide does not leave a chlorophyll *a* spike or signal derived from remote sensing applications. How were the samples enumerated? If they were enumerated, the archived data must now be available for inclusion in this project. If these data exist, we should have received them during database acquisition and analysis.

Page 18 (OF TAC COMMENTS TO PAGE 52 OF THE REPORT)
Fourth bullet on page 18. "Again, methods, results, and discussion within the subheadings are not consistently organized."

- As noted above, this report is not a science journal research article with the same format of sections from one component to the next: Abstract, Introduction, Methods, Results, Discussion, etc. For example, Component 2 provides a description of the indicators used in development of the Index of Eutrophication calculated in Component 3. This description feeds into Component 3, and the format of Component 3 also does not follow the standard format of Abstract, Introduction, Methods, Results, Discussion, etc. because of the subject matter. Similarly, the format of the other components of the report is also not organized consistently due to the nature of the subject matter and the objectives of the report. The current format reflects this.

Page 18 (OF TAC COMMENTS TO PAGE 53 OF THE REPORT)
Fifth and sixth bullets on page 18. Sentence has been revised.

Dissolved inorganic nitrogen concentrations in fact may not be directly linked to the blooms, which may be more closely aligned with the concentrations of dissolved organic nitrogen in the estuary (Glibert et al., 2001; Glibert and Legrand, 2006; Glibert et al., 2010).

Glibert, P. M. and C. Legrand. 2006. The diverse nutrient strategies of harmful algae: focus on osmotrophy. In: Graneli, E. and J. Turner (Eds.), *The Ecology of Harmful Algae*. Springer-Verlag, New York, pp. 163-175.

Glibert, P. M., et al. 2010. Blooms in lagoons: different from those of river-dominated estuaries. In: Kennish, M. J. and H. W. Paerl. (Eds.), *Coastal Lagoons: Critical Habitats of Environmental Change*. CRC Press, Boca Raton, pp. 91-114.

Page 18 (OF TAC COMMENTS TO PAGE 53 OF THE REPORT)
Seventh bullet on page 18. "What was the pattern in the number of clammers over this period; is there any trend in the CPUE?"

Data are not available to accurately assess CPUE for hard clams. No reliable data were found in this project for CPUE in Barnegat Bay. Ocean County hard clam landings data have been reported voluntarily from various sources over different periods of time and therefore are not very helpful. In addition, they were not reported at all after ~2005. Some individuals have tried to assess fishing effort by examining shellfish license sales, but this is not an accurate approach. One major reason for this is that license sales are statewide (and so cannot track license sales specific for Barnegat Bay). Please note that it is unknown whether someone uses a license for clamming once, ten times, or a hundred times. This precludes accurate assessment.

Page 18 (OF TAC COMMENTS TO PAGE 54 OF THE REPORT)
Eighth bullet on page 18. “The loss of such large numbers of hard clams…”

This sentence has been revised to the following: “The loss of such large numbers of hard clams may cause a shift or transition in the system away from one of top-down control exerted by filter feeders consuming and regulating phytoplankton populations to one of bottom-up control limited by nutrient inputs.”

Page 18 (OF TAC COMMENTS TO PAGE 54 OF THE REPORT)
Ninth bullet on page 18. “This section is far too much a diatribe against other large national monitoring programs rather than a clear presentation of why data were or were not used.”

We disagree with this comment. NCA data were not used in the index because they are not statistically or scientifically sound for use in the index, and that is the reason why the data were not used. This was clearly and explicitly stated in the report. We agree with the TAC comment that the adequacy of data depends on their use, and the NCA data are inadequate for use in the index development. The number of NCA stations sampled annually from 2000 to 2006 is not adequate for accurate statistical analysis of the benthic invertebrate community of the estuary, and so the data could not be used in this project.

This is clearly and objectively stated in the following paragraph on page 54 of the original report: “National Coastal Assessment (NCA) benthic invertebrate samples collected annually in the estuary from 2000 to 2006 were not sufficiently abundant to be used in index development for this project. For example, only 4 NCA benthic invertebrate samples were collected in 2000, 2003, and 2005, while 6 samples were collected in 2002, 10 in 2004, 15 in 2001, and 16 in 2006 (Table 2-10), far too few for adequate statistical analysis for the three segments of the estuary.”

We also provided additional information describing why the benthic invertebrate data were deficient on this system for use in the index development.

PAGE 18 OF TAC COMMENTS (TO PAGE 55 OF THE REPORT)
“Numerous datasets were excluded. Some discussion should be included here regarding what selection bias could occur by allowing and not allowing data sets.”

- We note that within the limits of data availability, the determination to include or exclude a particular dataset was made based on the representativeness of the sampling within the spatial and temporal scope of this project. Ideally, the aggregated database for this project would be as holistic and comprehensive as possible. However, when aggregating multiple datasets collected for a variety of purposes, it is necessary to avoid bias associated with sampling design that were not designed with the current purposes of this project in mind. Inclusion of datasets that are not representative of the temporal and spatial scale of this current project would result in biased and inaccurate conclusions from this project. We note that additional details and discussion regarding the decision of specific datasets are included in Appendix 3-2.

PAGE 18 OF TAC COMMENTS (TO PAGE 56 OF THE REPORT)
First bullet: "Component 53, Biotic Index Development. This component section has a different structure than previous component sections. Where are the methods? The results of the development of the index are presented as conclusions and are, without knowing what was done, inappropriate."

- This section of the report has been restructured to be more similar to other sections of the report. The Summary and Conclusion have been moved to the end of this section. Section headings have been modified to clearly indicate sections that detail methods, sections that detail results, and sections that discuss the results.

PAGE 18 OF TAC COMMENTS (TO PAGE 56 OF THE REPORT)
Second bullet: "The researcher states that the subject Biotic Index of Eutrophication is the most comprehensive and holistic assessment of BB-LEH conducted to date. In order to assess the ~20 indicators, the index integrates over 74,400 observations among 85 variables. However, the sheer number of observations, variables and/or indicators used does not validate the index. Data availability is likely a big factor is whether the index reasonably performs. The uncertainty must be discussed, including the effect of data availability."

- The report does not make the claim that the validation of the Index of Eutrophication is based on the quantity of data analyzed.
- Validation is conducted 1) through a sensitivity analysis that compares the Water Quality Index where weightings are conducted on an annual vs. a multi-year basis, 2) through comparison of results to previous assessments of Barnegat Bay by the ASSETS methodology, and 3) application of the Index of Eutrophication to an additional year of sampling (2010) that was kept separate from the rest of the database for validation purposes.
- Data availability is addressed through the weighting of indicators and the weighting of the Water Quality Index, the Light Availability Index and the Seagrass Response Index. When and where data are unavailable, weighting is established as 0. When and where data are available, weighting is based on the square of the eigenvector calculated through PCA. The effects of missing data for an indicator are tested using the Water Quality Index as an example. In this test case, total phosphorus data are available during 2000-2010 but not from 1989-1999. The Water Quality Index is calculated for 2000-2010 for scenarios that include and exclude total phosphorus to compare and validate the approach. Results indicated that Water Quality Index values were not significantly different between the two scenarios, even though the weighting of indicators varied in these two cases. From this result, we conclude that the index performs reasonably under both scenarios. The report discussed the effects of data availability and acknowledges the data availability is one limitation of this approach. This information is available in the sections of Sensitivity Analysis in Component 3 and the Validation Against the ASSETS Assessment in Component 4.

PAGE 19 OF TAC COMMENTS (TO PAGE 56 OF THE REPORT)
First bullet: "Data availability remains a major limitation to assessment of eutrophication condition for BB-LEH. While an increasing number of indicators are being monitored, aligning data collection through space and time and increasing sampling frequency will greatly improve future assessments." A similar conclusion is presented on page 68. We definitely agree. This is so important it should be listed as a "KEY FINDING."

- This information was indeed listed as a Key Finding (the fourth bullet of the report). It remains in the Key Findings section in the revision.

PAGE 19 OF TAC COMMENTS (TO PAGE 58 OF THE REPORT)
First bullet: "On the first bullet, just focusing on the central section: Light availability is increasing but it's greatly worsened in the central section. Chlorophyll a is good, suspended solids is excellent, epiphyte coverage is excellent and the percent light reaching seagrass is good. The overall conclusion was that light did not penetrate deep enough. On page 75, the water quality index was described as moderate and sometimes good. Watershed pressure indicators are considered good. The conclusion provided on page 75 on the seagrass response index indicates the condition is "highly degraded" to "poor". It appears that the factors don't support the conclusion that water quality, watershed pressures or light availability are responsible for the decline in seagrass."

- As written in the report, the conclusion regarding depth of light penetration refers to the north segment, not the central segment. Even so, the factors listed in the TAC comments omit macroalgal blooms, which due to the limited weighting received do not factor much into the Index of Eutrophication. These blooms, however, play an important role in the degradation of seagrass and limitation of light through shading. There has been a significant increase in the frequency of macroalgae blooms at very high percent cover (80-100 percent cover) over the study period. See Kennish et al. 2011, Fertig et al. 2012, other figures and previous responses to TAC comments for additional details. These supporting figures, documentation, and the role of macroalgae in the decline of seagrass in BB-LEH are cited through this section of the report, though not specifically in the bulleted list of conclusions, which have now been moved to the end of this Chapter.

PAGE 19 OF TAC COMMENTS (TO PAGE 58 OF THE REPORT)
Second bullet: "National Estuarine Eustrophication Assessment. The NEEA and the following Goals and General Approach Section are redundant and should be cut to focus solely on the methods that were developed and/or used. A revised methods section should be the first items presented within this component."

- The TAC requested information regarding how this study increases the quantification of eutrophication assessment and improves previous assessments of BB-LEH (such as the NEEA report) and how the methodology used for this project utilizes the basic methodology of the NEEA approach. Further, the TAC requested a comparison of the findings to that of Bricker et al., as specified on page 60 of the QAPP. See page 4 of the TAC comments (Comments on the Statistical Approach) and the response to the first bullet of that page. To comprehensively and adequately address all the TAC comments and provide context for a reader not already familiar with either the NEEA report or this project, it is necessary to describe the NEEA approach and clearly identify the methods and modifications that are developed and used for this project.

PAGE 19 OF TAC COMMENTS (TO PAGE 58 OF THE REPORT)
Third bullet: "Influencing Factors include Load (nitrogen ratio) and Susceptibility." Please explain your use of the term susceptibility. Is there a relevant citation? I thought the "pressures" identified in a previous section were N-load and residence time."

- We note: Bricker et al. (2007) define 'susceptibility' as "a measure of a system's nutrient retention based on flushing and dilution" (p. 12) and note "susceptibility is influenced by the flow of water. The flushing capacity of a system is determined by tidal action and the amount of freshwater flowing in from its tributaries."
- For the purposes of this project, Ecosystem Pressures refers to total nitrogen loading and total phosphorus loading (kg km^{-2} yr^{-1}). While residence time was initially considered for inclusion, ultimately it was determined it could not be quantitatively included in the Index of Eutrophication. Full documentation and justification for this is described in other responses to TAC comments.

PAGE 19 OF TAC COMMENTS (TO PAGE 59 OF THE REPORT)
Second bullet: "Background: Building on the NEEA: Where is the "matrix" that is mentioned in paragraph 2?"

- The ASSETS matrix for Barnegat Bay is shown in Figure 4-1 and the accompanying conceptual diagram is shown in Figure 4-2. Results from this project are compared to the NEAA assessment of Barnegat Bay as part of the validation, and thus this figure appears in Component 4 of the report.

PAGE 19 OF TAC COMMENTS (TO PAGE 61 OF THE REPORT)
Second bullet: "Please provide a justification for averaging the six variables together."

- Note that according to Table 3-15, based on data availability, the Index of Eutrophication is weighted as follows: 1) 1989-1997 Water Quality Index 100%. 2) 1998-2003: Water Quality Index and Light Availability Index both 50%. 3) 2004-2010: Water Quality Index, Light Availability Index and Seagrass Response: each 33%.
- We note here that indices for each of components with sufficient data are then averaged together for the sets of years when data are available to calculate the overall Index of Eutrophication. While ideally each index would be used as input for another PCA to calculate a weighting for each index, there was an insufficient quantity of data to do so and equal weighting (i.e. averaging) for years of available data for each index was considered justified as an alternative. Note that ultimately, weighting based on variability for the HAB index and the Benthic Invertebrate Index (during 2001) was ultimately weighted at 0% (Table 3-15).

PAGE 19 OF TAC COMMENTS (TO PAGE 61-63 OF THE REPORT)
"Available Data and Data Gaps: Please clarify the relative valuation of all these data sets. Explain why some datasets were held to stringent screening criteria (e.g., NCA data) while other datasets were used where location of the sampling was unknown (HAB dataset). It may also be

helpful to further expand the Section on Data Availability and Data Gaps to describe the quality assurance and quality control of the data."

- All datasets from all sources were held to stringent screening criteria. This includes, but is not limited to NCA and HABs data. Note that while thresholds are available to create an index for HABs, there is only one indicator available (cell concentration) and no PCA could be conducted so the HAB index is based solely on cell concentration. Yet, when included in analysis for the overall Eutrophication Index, it did not receive any weighting for any year.
- The QA and QC information requested is included in the Dataset Assembly section.

Page 20 (OF TAC COMMENTS TO PAGE 66 OF THE REPORT)
Seventh bullet on page 20. "Dissolved oxygen thresholds are defined relative to the New Jersey standard of impairment, which is established at 4 mg/l. There is a good amount of DO data for the bay…"

DO data has been systematically collected in the estuary since 1989. Regulatory protection and conservation of New Jersey's estuarine waters have been primarily based on grab samples for DO measurements at specific sampling locations. However, dissolved oxygen is only one indicator of ecosystem health, and it must be monitored continuously in multiple (statistically valid) locations for accurate assessments due to large variations over the course of a day driven by natural processes, most notably changes in temperature, light, as well as community photosynthesis and respiration. Taking one grab sample at multiple locations once a quarter, once a month, once a week, or even once a day, will not suffice – it will not provide statistically accurate, scientifically sound or valid measurements of DO in this shallow waterbody – a coastal lagoon. The variation is just too great. The same observations have been made for other coastal lagoons by Robert W. Howarth(Cornell University, personal communication) who has noted that "DO is often measured once a month, with no consideration of time of day for sampling; this may work work for bottom waters in a highly stratified estuary, but is meaningless in a shallow lagoon where DO may oscillate from say 20% of saturation every dawn to 200% of saturation every day at dusk." Previous DO samples collected by the NJDEP have been primarily obtained by collecting water samples during daylight in the morning to afternoon hours which adds sampling bias into the process. By this we mean that the results will bias results toward higher DO levels above the 4 mg/l standard. It is not possible to correct this without also collecting and factoring in DO measurements taken during the night hours, specifically from ~1 a.m. to 5 a.m. It is also necessary to collect at least three DO measurements every day to determine an accurate DO profile for a particular station. This has not been done previously, and so the prior database on DO in this estuary is deficient.

What is required in the future will be moored datalogger instrumentation at strategic locations around the estuary, deploying at least 10 dataloggers in each segment of the estuary for statistically meaningful results. If grab samples will be continued, then it will be necessary to collect at least 3 grab samples at each sampling station per day, and the sampling frequency must be increased to daily or perhaps no less than every other day for several years' time to obtain trends. By collecting 3 grab samples per day (with at least one measurement taken between ~ 1 a.m. and 5 a.m.) over annual periods, accurate modeling can be conducted. That would give a clear and accurate picture of the DO condition in the estuary for use in impairment assessment. The current frequency and time of day for collecting DO samples do not provide an accurate method of determining impairment of the estuarine waters.

The above discussion of DO monitoring for impairment is important in the context of Component 5 of the report. It also is important because it demonstrates the need to target multiple key indicators for accurate assessment of impairment and ecological condition of Barnegat Bay-Little Egg Harbor Estuary. Again, this was an important objective of the NEIWPCC project.

PAGE 21 OF TAC COMMENTS (TO PAGE 67-68 OF THE REPORT)
For biotic response, can we provide a figure with the observed response to an increase in nitrogen load?

- See Figures 3-14, 3-15, 3-16. These were included in the original submission of the report. Note however, that ecosystems work in complex, non-linear ways and examination of two variables at a time often misses this complexity.

PAGE 21 OF TAC COMMENTS (TO PAGE 68 OF THE REPORT)
Second bullet: "With limited data for benthic invertebrate components, can we determine that the index will accurately represent the response to the benthic communities with load increases? Do we have a comprehensive analysis on the current benthic community status for each segment?"

- No. Data for benthic invertebrate component is extremely limited. Even though there is sufficient spatial coverage for one year (2001) no other years of data exist with sufficient data for analysis, which results in an inability to be confident in the accuracy of the benthic community response to nutrient load increases. There is no comprehensive analysis on the current benthic community status for each segment that is available for this project. While the NJ DEP is currently funding a project to conduct benthic invertebrate community surveys for BBLEH, the results of that study cannot be considered for analysis by this project since the data are collected beyond the time period considered for this project, as specified by the QAPP.

PAGE 21 OF TAC COMMENTS (TO PAGE 74 OF THE REPORT)
"The index values are presented with the descriptors ranging from excellent to highly degraded. Were any other breaks considered such as eutrophic, mesotrophic, oligotrophic? Is there a breakpoint between acceptable and unacceptable conditions?"

- No, the descriptors used reflect the overall Index of Eutrophication as related to the thresholds for the various indicators. The definitions of eutrophic, mesotrophic, and oligotrophic do not holistically incorporate the various biotic responses pertinent to BB-LEH, but rather are more general and generic terms used to describe rates and loads of organic matter and nutrients to an ecosystem. Comparisons between these are therefore both difficult since they are essentially apples and oranges.
- Acceptability and unacceptability of conditions regarding eutrophication are ultimately based upon value judgments outside the realm of scientific inquiry. We do not wish to

> overstep the bounds of what is objectively and scientifically defensible. The Index of Eutrophication provides a tool to assess the holistic condition of BB-LEH with regards to available data for many indicators and to specify the relationship of condition with various levels of each indicator that interact dynamically. However the acceptability of various conditions depends the values of the community stakeholders, advocacy groups, environmental management and other government/regulatory agencies, and other entities.

Page 23 (OF TAC COMMENTS TO PAGE 90 OF THE REPORT)
First bullet on page 23. "Synthesis and Management Recommendations. This section is more of a literature summary of impairments and eco-shifts covered in the introduction due to human impacts and the need to develop a holistic plan to reduce these stressors."

First, it is necessary to state how impairment is defined for this system, and if the system is, in fact, impaired. DO data collected in the estuary over the 1989-2011 timeframe do not accurately provide this information as noted above (see response to page 20 of TAC comments to page 66 of the report). It is also necessary to state on what basis the system is impaired – if it violates criteria or specific mandates.

The New Jersey Department of Environmental Protection has adopted rules establishing a Narrative Nutrient Criteria for Barnegat Bay-Little Egg Harbor. This is constructive. It is important to note that eutrophication impacts in the estuary reported in the published peer-reviewed literature (see below citations) and documented in the NEIWPCC Report appear to violate the State's Narrative Nutrient Standard (NJAC 7B-1.14(d)4.i.), which states that:

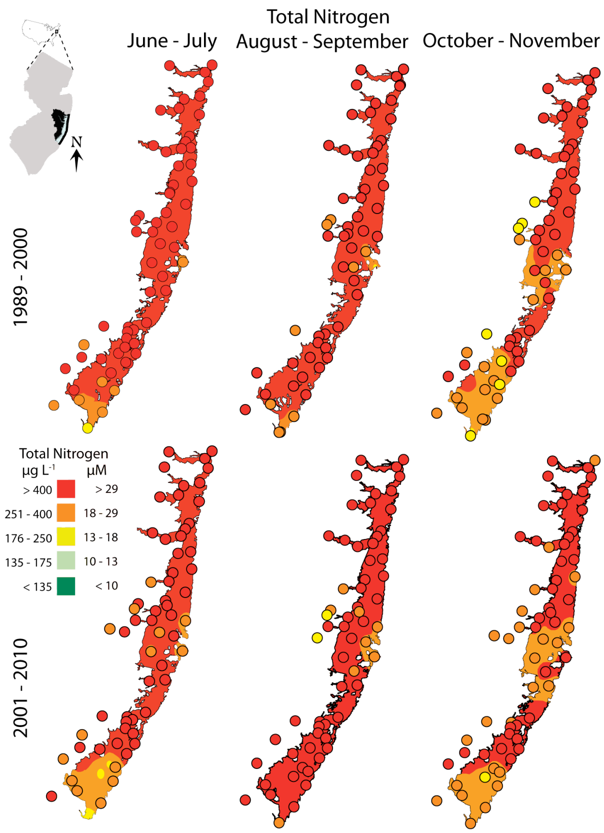
"Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses due to objectionable algal densities, nuisance aquatic vegetation, diurnal fluctuations in dissolved oxygen or pH indicative of excessive photosynthetic activity, detrimental changes to the composition of aquatic ecosystems, or other indicators of use impairment caused by nutrients."

Barnegat Bay-Little Egg Harbor is a eutrophic system impacted by eutrophication (Seitzinger et al., 1992, 2001; Bricker, 2007, 2009; Kennish et al., 2007, 2008, 2010; Kennish and de Jonge, 2010; Kennish, 2009; Fertig and Kennish, in press). : Eutrophication is defined as the process of nutrient enrichment and increase in the rate of organic matter input in a waterbody leading to an array of cascading changes in ecosystem structure and function such as decreased dissolved oxygen levels, increased microalgal and macroalgal abundance, occurrence of harmful algal blooms (HABs), loss of seagrass habitat, reduced biodiversity, declining fisheries, imbalanced food webs, altered biogeochemical cycling, and diminished ecosystem services. This does not mean that all of these impacts have to occur concurrently or even over a projected period of time, but it does mean that a number of these impacts occur in the system concurrently and that they are detrimental, resulting in negative impacts, such as those documented repeatedly in the published literature and on this estuary.

PAGE 23 (OF TAC COMMENTS TO PAGE 91)
"Figure 5-2 should be revised to reflect the expression of nitrogen based on the selected

threshold."

- We have revised Figure 5-2 to show decadal mean total nitrogen concentrations and their spatial interpolation with respect to the threshold for total nitrogen, which has been used for the Index of Eutrophication. The revised figure, included in the report, is shown below.



PAGE 23 (OF TAC COMMENTS TO PAGE 90-101)

"Component 5, Synthesis and Management Recommendations: The scope of work for this project specified that "thresholds levels of biotic decline and numeric nutrient loading criteria will be developed for the estuary and discussion of how these threshold levels can be integrated into a management plan will be given". On page 40, the report states that "recommendations for developing a management plan based on our findings will be given and additional data and analysis needed to improve the plan will be listed. The discussion that currently exists in this section needs to be expanded to adequately fulfill this task."

- Thresholds of indicators are included in the tables and have been referenced multiple times in this response. These are developed in support of nutrient management planning. However, it must be understood that these ranges and factors have complicated interactions, and none operation individually or statically. It is outside the scope of this project and this report to identify the factors that can be remediated most cost effectively. Neither cost-effectiveness nor remediation is mentioned in the QAPP. Hence, this project is **in support of** nutrient management planning, but does not overstep its bounds by presuming to develop an effective management plan. Development of numeric nutrient loading criteria is beyond the scope of work, as defined by the QAPP.

- The discussion and recommendations for developing a management plan based on the findings in this report have been revised and expanded on.

PAGE 23 (OF TAC COMMENTS TO PAGE 91)

"Human factors should also include recreational usage, although not evaluated thru this project. Example –watercraft may be resuspending sediment and damaging SAV beds."

- Recreation usage and other human factors are not specified in the QAPP and are beyond the scope of work for the project.

Page 23 (OF TAC COMMENTS TO PAGE 92 OF THE REPORT)

Sixth bullet on page 23. "Based on GIS analysis…most of this wetland loss has occurred along the bay and tidal waterway shorelines. This was taken from the BBP 2011 SOTB Report which should be correctly identified to source."

Richard Stockton College Coastal Research Center is the source of the GIS analysis. Citations always revert to original source of the work, not the funding source for the work. If citations were done on the basis of funding source, science citations in the published literature would have to be radically revamped.

We will therefore cite Richard Stockton College Coastal Research Center as the primary and original source of this analysis, as we noted already. We will also cite the BBP 2011 SOTB Report, although this is the secondary source of the data.

Page 23 (OF TAC COMMENTS TO PAGE 95 OF THE REPORT)

Seventh bullet on page 23. "The report suggests that extensive macroalgal blooms were recorded and have persisted through the ensuing years (2008-2010). However, Table 2-1 shows June-July 2008 had the highest percent macroalgae cover at 20% while for most other periods the coverage was less than 10%."

The values noted above by the TAC are mean values of macroalgae cover during the study periods. They do not reflect absolute macroalgae cover during the study period. As noted in the report and in a peer-reviewed publication on this work (Kennish et al., 2011), the investigations of macroalgal blooms in the estuary over a six-year period for this project documented 55 occurrences (2.23 blooms m-2) of Early Bloom (70%–80% macroalgal cover) and Full Bloom (>80% macroalgal cover) events. Obviously, these are not the 20% or 10% figures noted above by the TAC.

PAGE 23 (OF TAC COMMENTS TO PAGE 97)

"" When TN loading exceeds some critical threshold value there is a triggering of phytoplankton and macroalgal blooms, as well as increased epiphytic growth, that can significantly reduce light transmission to seagrass beds, leading to acute die-offs of the seagrass and the resident shellfish and other benthic invertebrates inhabiting the beds." Please provide the threshold value nitrogen loading as well as the scientific basis for the selected threshold."

- We have revised the statement quoted above as a more general statement. Thresholds of total nitrogen concentration used for the Index of Eutrophication are included in Table 3-8 but, since the discussion of this paragraph is more general, it is inappropriate to reference a BBLEH-specific threshold here.

Page 23 (OF TAC COMMENTS TO PAGE 98 OF THE REPORT

Ninth bullet on page 23. "The first paragraph indicates that the dissolved oxygen listing was based on continuous monitoring while the second paragraph indicates that this level of monitoring has not been done in Barnegat Bay."

The first paragraph under "Dissolved Oxygen" in Component 5 of the report has been revised to address this comment.

Page 24 (OF TAC COMMENTS TO PAGE 98 OF THE REPORT)

Second bullet on page 24. "This listing for the north segment is based on continuous water quality monitoring… Is this true?"

The listing is based on grab samples collected routinely in the estuary. This has been corrected in the first paragraph under "Dissolved Oxygen" in Component 5 of the report.

Page 24 (OF TAC COMMENTS TO PAGE 99 OF THE REPORT)

Third bullet on page 24. "Sea nettles are not used as an indicator of impairment of swimmable waters and also not in NJ's assessment methodology for assessing primary contact recreation. The following sentence…should be removed, "High abundances of sea nettles have made bathing beaches and other waters in the estuary non-swimmable, creating impairment for human use." "

We have revised the sentence to: "High abundances of sea nettles have posed a hazard to human use of some areas in the north segment of the estuary."

Page 24 (OF TAC COMMENTS TO PAGE 99 OF THE REPORT)

Fourth bullet on page 24. "This statement is not correct and should be removed. The occurrence of sea nettle blooms…"

This paragraph has been deleted.

Page 24 (OF TAC COMMENTS TO PAGE 99 OF THE REPORT)

Fifth bullet on page 24. “Please identify the BBP report as the source of Figure 5-5 in the report.”

The BBP State of the Bay Report has been cited as the source of Figure 5-5.

Page 24 (OF TAC COMMENTS TO PAGE 99 OF THE REPORT)
Sixth bullet on page 24. Need to revise the following sentence: “The occurrence of sea nettle blooms in the north segment has resulted in extensive non-swimmable waters in violation of the Clean Water Act (Figure 5-6).” There is no standard or criterion for jellyfish, so this statement is incorrect. Not everyone may agree, but one potential modification would be to suggest that a standard/criterion for jellyfish be explored by state and federal regulatory agencies.”

This sentence has been deleted.

Page 24 (OF TAC COMMENTS TO PAGE 100 OF THE REPORT)
Seventh bullet on page 24. “The last two sentences in the second to last paragraph on sea nettles should be deleted.”

These two sentences have been deleted. We have added the following sentence to the end of this paragraph: “There also needs to be more administrative/management assessment of the problem.”

Page 24 (OF TAC COMMENTS TO PAGE 100 OF THE REPORT)
Eighth bullet on page 24. “Add Condon citations.”

Citations have been added.

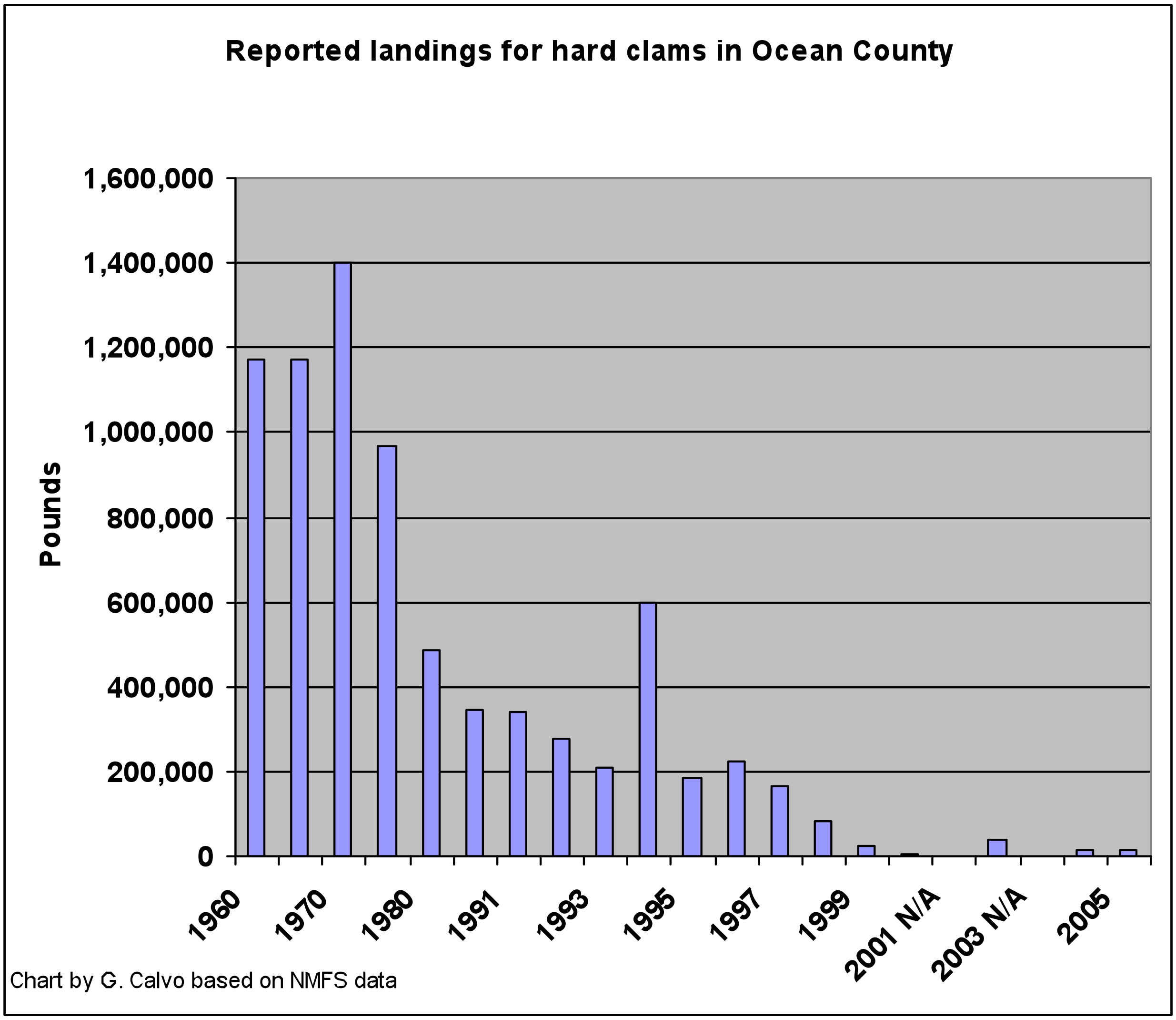
Sea Nettle Citations
Condon, R., M.B. Decker, and J. E. Purcell. 2001. Effects of low dissolved oxygen on survival and asexual reproduction of scyphozoan polyps (*Chrysaora quinquecirrha*). Hydrobiologia 451: 89-95.

Decker, M. B., C. W. Brown, R. R. Hood, J. E. Purcell, T. F. Gross, J. C. Matanoski, R. O. Bannon, and E. M. Setzler-Hamilton. 2007. Predicting the distribution of the scyphomedusa *Chrysaora quinquecirrha* in Chesapeake Bay. Marine Ecology Progress Series 329: 99-113.

Page 24 (OF TAC COMMENTS TO PAGE 100 OF THE REPORT)
Ninth bullet on page 24. “These numbers are indicative of an ongoing insidious ecological decline of the estuary. The cause of this dramatic decline has not been unequivocally established, although the diminution in hard clam landings has occurred during an escalating period of nutrient enrichment and eutrophication of the estuary...”

"I think it is more appropriate to emphasize the need for additional shellfish research into the causes of shellfish decline (e.g., overfishing due to inadequate fishery management) and the resources needed to promote the shellfish industry."

The dramatic decrease of shellfish absolute abundance and shellfish harvest statistics are symptoms of an estuary in ecological decline. We believe that it is necessary first and foremost to describe the status and trends of the hard clam resource in the estuary, since an important indicator of eutrophication is fishery decline, often linked to seagrass decline (Nixon et al., 2001; Hughes et al., 2002). There are two lines of evidence that the hard clam population has been in a state of steady or insidious decline: (1) hard clam surveys conducted in State surveys; and (2) gradual declining hard clam landings over a 30-year period (see below) which parallel and are consistent with diminishing absolute abundance figures for the species. We do agree with the TAC comments, however, that request the need for additional research on shellfish in the estuary – and, more importantly, more frequent shellfish surveys to assess stock. We do view the current database on hard clams as one of a clearly declining resource and an acutely declining population, reflecting with other indicator data a declining ecological condition of the system. It is also not possible to reject eutrophication as a possible primary cause of these declines, especially when the declines have occurred concurrently with nutrient enrichment problems in the estuary.



PAGE 25 OF TAC COMMENTS (TO PAGE 140 OF THE REPORT)
"Figure 3-2 shows that REMAP sediment TOC was used in the index but the section describing the indicators (pg. 60) doesn't include this indicator."

- Sediment TOC was not used as an indicator for the benthic invertebrate index. This indicator has been removed from Figure 3-2. There are only four indicators that are used for the benthic invertebrate index, as noted in the section "Index of Eutriphication: Goals and Approach": 1) Species richness, 2) Gleason's D value, 3) EMAP index values, and 4) Hard clam abundance. Figure 3-2 is revised accordingly.

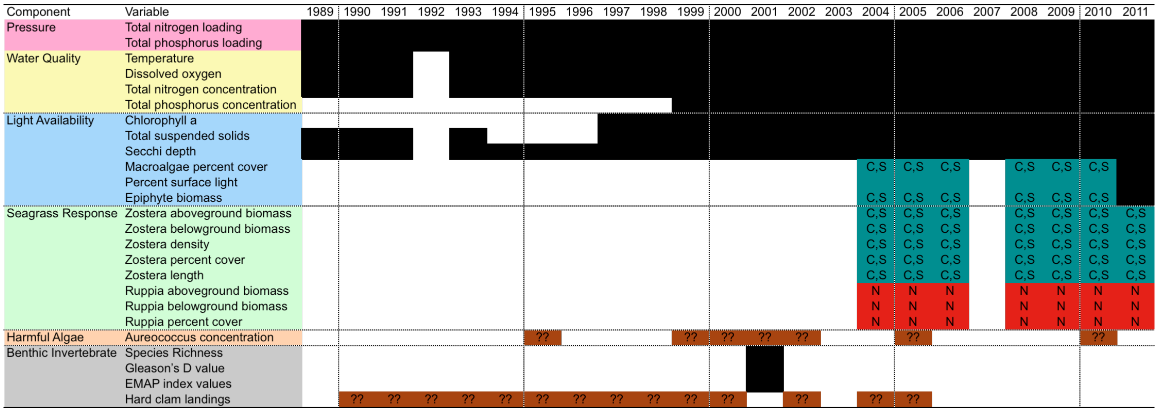


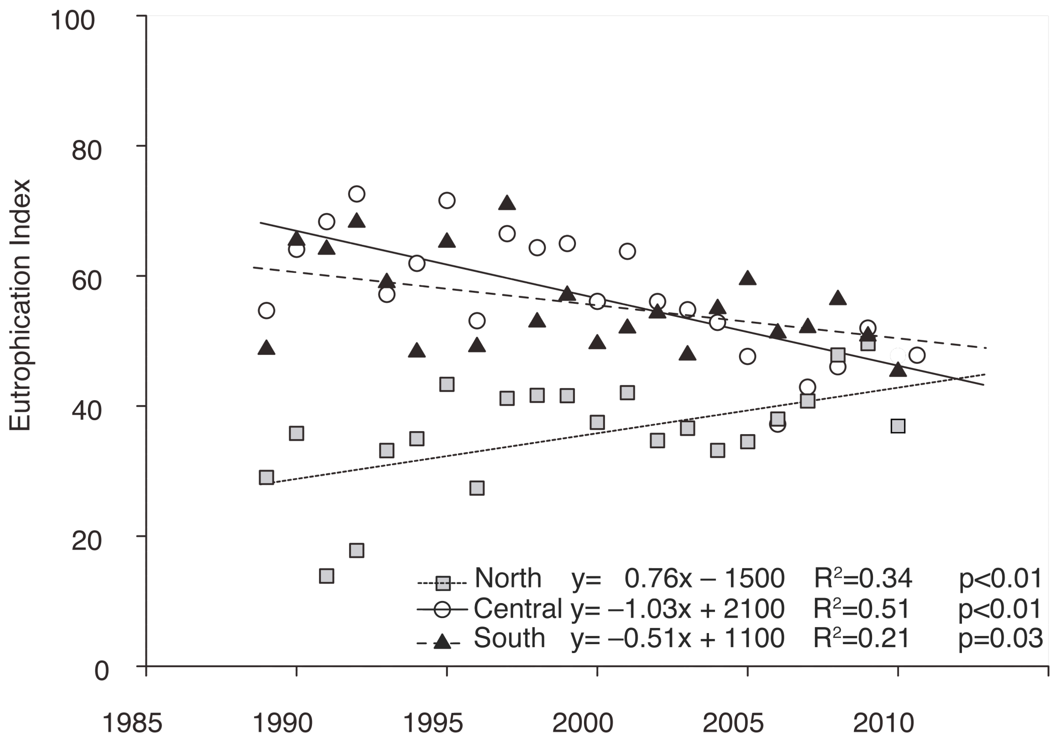
Figure 3 - 2. Temporal and spatial data availability for indicators used in the Index of Eutrophication.

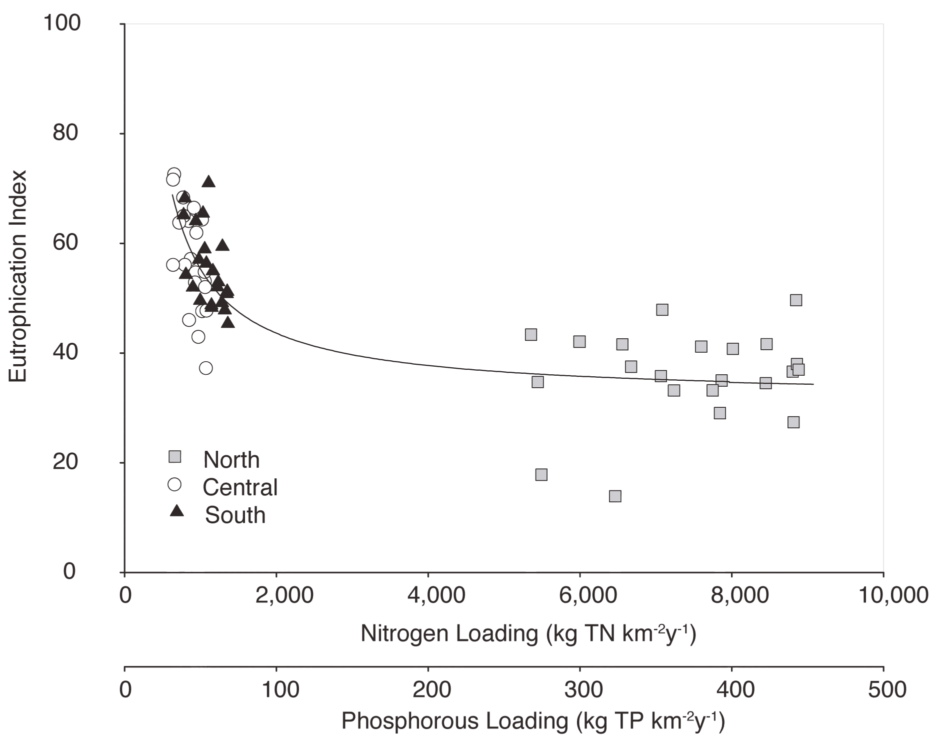
PAGE 25 OF TAC COMMENTS (TO PAGE 182 OF THE REPORT)
"Figures 5-5 and 5-6 should include the source of the sea nettle data."

- We cite Barnegat Bay Partnership as the data source for Figure 5-5. Figure 5-6 was generated by Rutgers based on field observations and analysis.

PAGE 26 OF TAC COMMENTS (TO FIGURE 3-39)
"Overall Eutrophication Index: A trend line should be fitted to each segment in order to evaluate the estimated direction/trend of the index. However, the feasibility and appropriateness of fitting a line should be considered after other comments have been addressed."

- We have fitted a trendline for each segment of the bay to test for significant trends over time.





PAGE 26 (OF TAC COMMENTS TO APPENDICES):
"Appendix #1 (starting on Page 211) and Appendix #3 (starting on Page 324) were submitted with the report. Is there an Appendix #2?"

There is an Appendix #2. Appendices are numbered with respect to the component of the report they are appended to. Appendix 1 (the USGS section of the report) thus is an appendix for Component 1. Appendix 2-1 is a full report comparing remote sensing of seagrass to in situ measurements and is an appendix for Component 2. No appendix is necessary for Component 4 or Component 5. There are five appendices for Component 3. Appendix 3-1 is the equations and SAS code for the calculation of percent surface light reaching seagrass leaves. Appendix 3-2 is the description of the additional datasets considered but ultimately not included in the Index of Eutrophication and the statistical justification for this decision. Appendix 3-3 is the SAS code used to assemble the various datasets into the SAS database for the Index of Eutrophication. Appendix 3-4 is the complete dataset, summarized by Year and Segment, that was used for the Index of Eutrophication. Appendix 3-5 is the SAS code used for calculating the Index of Eutrophication.

PAGE 26 (OF TAC COMMENTS TO CITATIONS/REFERENCES):

• Page 27 - text includes citation: " Velinsky et. al., 2010", while the reference section (on page 113) lists " Velinsky et. al., 2011". Please clarify.

It is 2011.

• Page 40 - citation EPA-822-B-01-003, 2001 is not listed in the references section.
Nutrient Criteria Technical Guidance Manual Estuarine and Coastal Marine Waters. USEPA, Office of Water Publication 4304, October, 2001. 362 p.

• Pages 35, 41 and 233 - citation "USEPA, 2001" is not listed in references section.
Same as above.

• Page 65 - citation "Deegan et al., 2002" are not listed in references section.
Deegan, L.A, 2002, Wright, A., Ayvazian, S.G., Finn, J.T., Golden, H., Merson, R.R., and Harrison, J. Nitrogen loading alters seagrass ecosystem structure and support of higher trophic levels. Publication: Aquatic Conservation: Marine and Freshwater Ecosystems 12(2): 193-212, 2002.

• Pages 65 and 147 - citation "Tomasko et al., 1996" is not listed in references section.
Tomasko, D.A., Dawes, C.J., and M.O. Hall. 1996. The effects of anthropogenic nutrient enrichment on turtle grass (Thalassia testudinum) in Sarasota Bay, Florida (USA). Estuaries. 19: 448-456.

• Page 66 - citation "Burkholder et al., 2001" is not listed in references section.
Burkholder JM (2001) Eutrophication and oligotrophication, pp. 649-670. In: Encyclopedia of Biodiversity, Vol. 2, by Levin S (ed.). Academic Press, New York.

• Page 67 - citations "Weisberg et al., 1997", " Van Dolah et al., 1999", and " Hale and Heltshe, 2008" are not listed in references section.
Weisberg, S.B., J.A. Ranasinghe, D.D. Dauer, L.C. Schnaffer, R.J. Diaz, and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. Estuaries 20(1):149-158.

Van Dolah, R. F., J. L. Hyland, A. F. Holland, J. S. Rosen, and T. R. Snoots. 1999. A benthic index of biological integrity for assessing habitat quality in estuaries of the Southeastern United States. Marine Environmental Research 48: 269-83.

Hale, S.S. and J.F. Heltshe. 2008. Signals From the Benthos: Development and Evaulation of a Benthic Index for the Nearshore Gulf of Maine. Ecological Indicators.V. 8: 338 - 350 Contribution No. AED-06-091.